BC

Ministry of Forests

Hon. Tom Waterland
Minister

85-5646/

FOREST RESEARCH REVIEW

1983-84

A report of the highlights of the
Ministry of Forests Research Program

BC

Ministry of Forests

Hon. Tom Waterland
Minister

British Columbia Cataloguing in Publication Data

British Columbia. Ministry of Forests. Research Branch.
Forest research review.—1978/79—

Annual.
Report year ends March 31.
Indexed by: Biological abstracts ISSN 0006-3169
Continues British Columbia. Forest Research Division. Forest research review ISSN 0068-1539
ISSN 0068-1539 = Forest research review (Victoria)

1. British Columbia. Ministry of Forests. Research Branch. 2. Forestry research – British Columbia.
I. Title.

SD 14.B7B74 354.711'0082'338042

© 1985 Province of British Columbia

Published by the
Information Services Branch
B.C. Ministry of Forests
1450 Government St.
Victoria, B.C.
V8W 3E7

Copies of this and other Ministry of Forests titles are available from Queen's Printer Publications, Parliament Buildings, Victoria, and their agents.

TABLE OF CONTENTS

DIRECTOR'S REPORT 1

HARVESTING RESEARCH 3

Wildlife Habitat Research 5
- Mule Deer in the Interior Douglas-fir Zone of British Columbia 5
- Intensive Forestry Effects on Deer and Elk on Vancouver Island 6
- Coastal Grizzly Bear — Forestry Interactions 6
- Wildlife Habitat Handbooks 7

Fish/Forestry Interaction Program 8

Engineering Research 10
- Road Recorder 10
- Log Haul Program 10
- Harvest Feasibility Study 10

SILVICULTURE RESEARCH 11

Interior Spruce 13
- Seed and Nursery Operations Research 13
  - *Container Seed Orchard Research* 13
  - *Testing Seed Performance by Cold Temperature Germination* 14
  - *Vegetative Reproduction with Cuttings* 14
  - *Cold Storage Physiology of Interior Spruce Seedlings* 14
  - *Linear Programing Model for Nursery Systems* 15
- Regeneration Research 15
  - *Improving Forest Planting Stock* 15
  - *Seedbed Density and Seedling Spacing* 15
  - *Genetic Improvement in Interior Spruce* 16
  - *Application of Slow-Release Fertilizers* 16
  - *Effects of Prescribed Burning* 16
  - *Measuring Plantation Growth Performance* 16
  - *Determination of Biological Stress Relationships* 17
  - *Boreal Backlog Reforestation Research* 17

Lodgepole Pine 19
- The Lodgepole Pine Tree Improvement Program 19
  - *Provenance Growth* 19
  - *Cone and Seed Production in Grafted Lodgepole Pine* 19
  - *Needle Cast (*Lophodermella concolor*) Infection* 20
  - *Selective Breeding Program* 20
- Growth and Yield Research 21
  - *Yield Prediction* 21
  - *Periphysis in the Repression of Lodgepole Pine* 21
  - *Thinning Lodgepole Pine with Roundup* 21
- Regeneration and Protection Research 21
  - *Cone Distribution after Feller-Buncher/Grapple-Skidder Logging* 21
  - *Snowshoe Hare Damage on Juvenile Lodgepole Pine* 22

Coastal and Interior Douglas-fir 23
- Seed and Nursery Operations Research 23
  - *ULV Sprays for Gibberellin Application* 23
  - *Collecting Seed at Natural Seedfall* 23
  - *Supplemental Pollination and Pollen Competition* 23
  - *Mitotic Index as Physiological Indicator of Seedling Dormancy* 24
  - *Phosphorus Fertilization and Wider Spacing in Seedling Growth* 25
- Genetics and Tree Improvement in Douglas-fir 25
  - *Douglas-fir Breeding Programs* 25
  - *Testing Douglas-fir Rootstock Compatibility* 26

Silviculture and Harvesting Support 26
Forest Water Balance Models for Stand Management 26
Developing Silvicultural Prescriptions for Drybelt Douglas-fir 26
Growth and Yield Research in Coastal Douglas-fir 27
Correlated Curve Trends 27
Managed Stand Yield Tables 27
Forest Regeneration 28
Fall Planting Guidelines for the Vancouver Forest Region 28
Western Hemlock 29
Crown Management in Western Hemlock Seed Orchards 29
The Western Hemlock Breeding Program 29
Regeneration Performance Assessment 29
Western Redcedar 30
Pelleting Tree Seed to Improve Precision and Efficiency in Sowing 30
Effect of Deer Browsing on Early Growth of Conifers 30
True Firs 31
Improving Seed Performance 31
Performance of Noble Fir in High-Elevation Species and Stock Type Trials 31
Ponderosa Pine 33
Effects of Initial Spacing on Growth and Development 33
Yellow-Cedar 34
Hedging Orchard Research 34
The Ecosystem Classification Program 35
Purpose 35
Application 35
Implementation 35
Site Protection and Rehabilitation 37
Watershed Rehabilitation Operations for Forested Slopes 37
Roadside Erosion Control Through Hydroseeding 37
Native Shrub Propagation: Users Guide 38
Forest Vegetation Management in British Columbia 39
Problem Analysis Completed 39
Operational Trials 39
Engineering Research 39
PROTECTION RESEARCH 41
Fire Studies 43
Reports Available 43
Equipment Development 43
Forest Pest Studies 43
Use of Bark Beetle Aggregating Pheremones 43
Second-Growth Pests 43

RANGE RESEARCH 45
Biological and Economic Effects of Range Fertilization 47
Range Management Bibliographies 47
LIST OF ACTIVE EXPERIMENTAL PROJECTS 51
1983-84 RESEARCH PUBLICATIONS 58
EMPLOYEES OF THE MINISTRY OF FORESTS, RESEARCH BRANCH 61

DIRECTOR'S REPORT 1983/84

The Research Program of the Ministry of Forests is an applied research program. Its responsibilities include: staying abreast of technological developments, finding solutions to problems, and assisting in incorporating improved management techniques in operational practice. To ensure that the program activities are focused on problems of major importance to the operational programs (Silviculture, Harvesting, Protection, etc.), a system designed to elicit operations input in problem identification and priority setting has been developed. Annually, district and region operations staff in each of the six regions meet with region and branch research staff as a Regional Research Advisory Committee to identify problems requiring solutions. Collectively they establish the relative priority for the resolution of these problems. The input from each Regional Research Advisory Committee and various Technical Committees is then summarized at the provincial level. The Chief Forester with representatives from the Branches and the Regional Research Advisory Committee meet as a Provincial Research Advisory Committee to develop the priorities for the initiatives to be pursued in the Research Program. It is the results of this process which have guided the development of the research initiatives presently in place in the Ministry.

This year's Forest Research Review represents a major departure in format from those of past years. The original format was designed to provide an annual update of each project in the program, providing relatively detailed information. However, as the program expanded, this format generated a large and perhaps intimidating report that failed to encourage the readership of the generalist unfamiliar with the specific research activities. In developing the new format, we have attempted to produce a document which provides an overview of the major thrust of the program relative to each operational program. As this is a new approach, we would appreciate receiving comments from our readers indicating the acceptability of this format. If it is not an improvement we want to know what would be more appropriate.

Research Program expenditures in 1983/84 amounted to 7.9 million dollars which included 6.0* for headquarters research, and 1.9 million for regional research. Other research expenditures were harvesting 0.5 million, and Section 88 (licensee) research 0.5 million dollars. In the past year, staff in the Research Program wrote 20 chapters in books; presented 23 conference papers; published 13 papers in refereed journals; and prepared six published reports and 56 unpublished special purpose reports documenting research results. In excess of 600 individuals from government and industry were trained in a wide range of topics, such as ecosystem identification and use in forest and range management, hydroseeding in erosion control, and determining cone and seed maturity for harvest timing. Cowichan Lake Research Station propagated 30 000 grafts of six tree species for the Coastal and Interior Tree Improvement Programs. In supporting the nursery and seed orchard operations and specific research projects, the Analytical Laboratory analyzed 6100 soil and foliar samples.

Research in the Harvesting Program primarily addresses support of issues or problems which impact the harvesting of the timber resources. The approach has been to develop interagency co-operative research programs to address these problems. Initiatives in place include the Queen Charlotte Island Fish Forestry Interaction Program, now in the third of a five-year program; and the Integrated Wildlife Intensive Forestry Research program on Vancouver Island, now in the fourth year of a six-year program. In addition to these major projects, smaller efforts are under way to examine options for harvesting mule deer winter range in the interior and to assess the effect of timber harvesting activities on coastal grizzly bears and their habitat.

In the southern interior of B.C., where a major concern is water supply, a new watershed study was established near Penticton. This project is designed to provide information on the impact of forest harvesting on water supply.

In addition, the growth and yield group provided estimates for managed stand growth to assist in the timber supply analysis for two Timber Supply Areas in the province this year.

The largest effort has been directed to supporting the Seed Operations, Nursery Operations, Basic Silviculture and Intensive Silviculture activities in the Silviculture Program. This past year, in support of Seed Operations, results of provenance and progeny tests were used to guide a revision of seed transfer rules and seed zone boundaries for white spruce. The best families from the 10-year-old open pollinated spruce progeny tests were identified for incorporation in 1.5 generation spruce seed orchards. The 10-year results from the range-wide lodgepole pine provenance tests were collected and a lodgepole pine breeding strategy was formalized. In support of the established plans of the Tree Improvement Councils, several hundred thousand seedlings of interior Douglas-fir, interior spruce, lodgepole pine and western hemlock were grown for the respective progeny testing activities. Continued research into containerized seed orchard opportunities has allowed the definition of conditions essential to ensure vigorous flower and

* Includes 0.2 million in contributions from the B.C. Ministry of Environment and Canada Department of Fisheries and Oceans for the jointly funded Queen Charlotte Islands Fish/Forestry Interaction Program.

cone production on young (≤ 5 yr) grafted ramets of interior spruce.

In supporting Nursery Operations, pilot scale testing of precision sowing equipment continued this year with small seeded species. This work follows a natural evolution from earlier research work which established the impact of nursery bed seedling density on final planting stock quality. Research continued to focus on refining cultural and stock handling practices (nutrition, root culture, seedbed density, cold storage) essential to improving nursery stock quality. Special emphasis was placed on developing and refining physiological stock testing procedures. In addition, efforts were directed to developing tools to aid nursery managers and silviculturists in evaluating the cost effectiveness of different white spruce stock types in their regeneration strategy.

In supporting the Basic Silviculture activities, the province-wide ecological classification initiative continued to make progress towards completion of the mapping phase. In keeping with the priority placed on white spruce in the provincial regeneration program, a multidisciplinary ecophysiology research project was begun. This research is designed to develop a fundamental understanding of the response of white spruce seedlings to environmental stress encountered on the outplanting site. In this way research staff expect to improve the ability to prescribe site preparation treatments. A problem analysis on seral ecosystem classification was initiated to allow a refinement in site specific vegetation management prescriptions. Ongoing efforts continued to address a wide range of issues associated with stand regeneration, such as evaluation of new stock types, season of planting, effective use of herbicides, species choices, and prescribed fire impacts.

Support for the Intensive Silviculture activities concentrated on improving the ability to predict response to fertilization and thinning treatments. This past year, interim managed stand yield tables for lodgepole pine were developed. Several new spacing and thinning experiments were established for lodgepole pine and an espacement trial for western redcedar was established in the Prince Rupert Forest Region. Analytical work was also initiated to develop new site index curves for interior spruce.

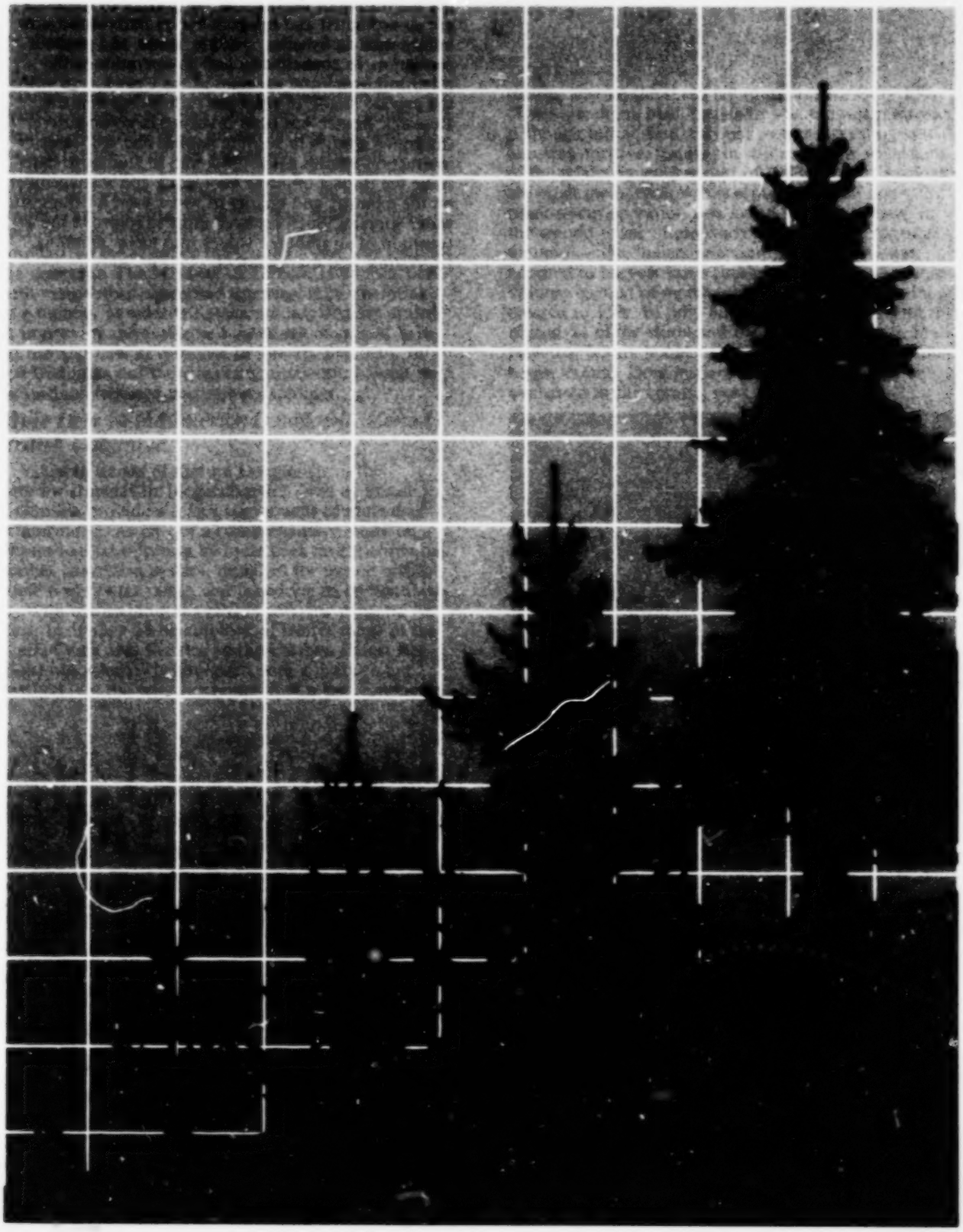
Research in support of the Range Management program emphasized a continuation of the range fertilization project and the problem analysis of range research needs.

The British Columbia Forest Service and the Canadian Forestry Service have in place an agreement which assigns the primary responsibilities for Forest Protection Research to the Canadian Forestry Service. As in the past, the Forest Service has assisted the CFS program by providing advice in identifying problems, and providing support where possible. The Forest Service has research under way to assess the extent and impact of small mammal damage on interior lodgepole pine and has undertaken extensive development designed to improve operational fire management systems.

While there have been difficulties associated with a reduced human and financial resource available to address the large number of high priority problems, substantial progress has been made on a wide range of topics. This progress is a testament to the ingenuity and dedication of the scientific staff in the Research Program and to the support provided by their fellow practitioners.

Dr. J.A. Dangerfield
Director

HARVESTING RESEARCH



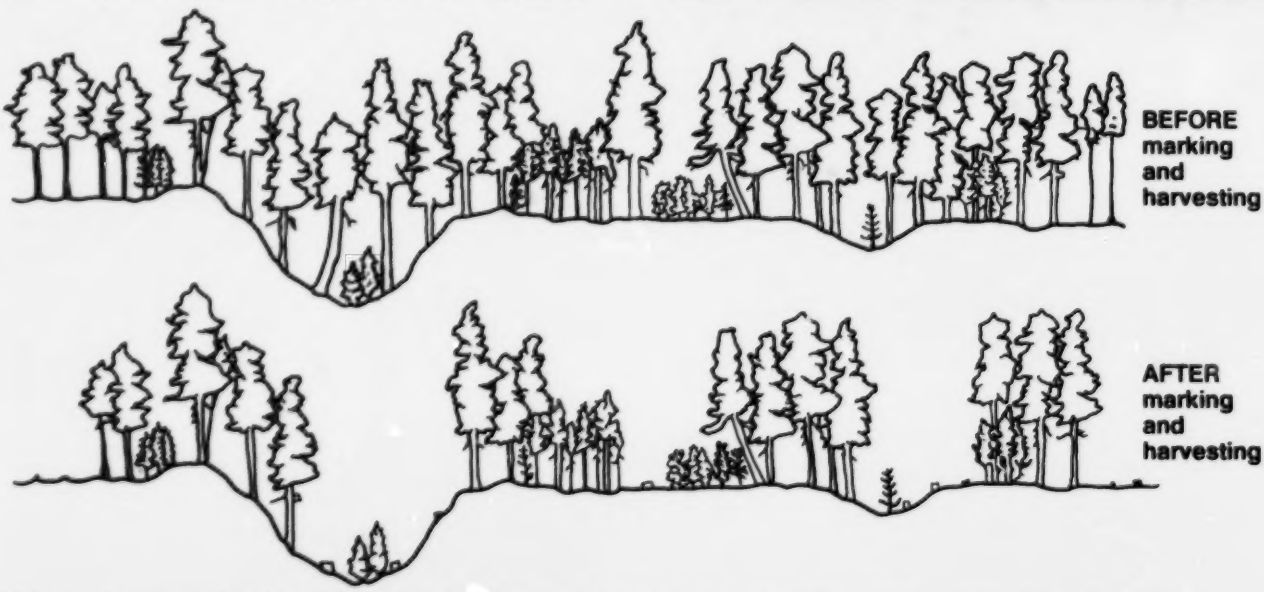
One of the purposes of the Ministry of Forests is to plan the use of the forest and range resources of the Crown so that the production of timber and forage, the harvesting of timber, and the grazing of livestock are co-ordinated and integrated with natural resource values such as fisheries, wildlife, water, and outdoor recreation, in consultation and co-operation with other ministries and agencies of the Crown, and with the private sector. In response to this requirement, Research Branch has been involved in co-operative, integrated studies in wildlife habitat and fish/forestry interaction studies since 1980; and in studies to determine the impact of forest harvesting and management on the quantity and quality of water used for domestic water supplies. Such research aims to improve the integration of all resource values into forest planning, harvesting, and management.

Forest stands valued for timber production in British Columbia are also often important wildlife habitats. Present rates of timber harvest and some intensive forestry activities are rapidly disrupting or eliminating ranges, and consequently endangering wildlife populations. Efforts to resolve such resource conflicts and the inherent delays they inflict on harvest plan approvals and the referral process have emphasized the need for integrating forest and wildlife management. The Ministry of Forests, in conjunction with many other concerned agencies, is co-operating in a number of wildlife habitat studies that are aimed at improving the available knowledge of animal habitat use and habitat response to forestry practices. In 1983/84, many of these investigations into habitat relationships reported preliminary findings.

Mule Deer in the Interior Douglas-fir Zone of British Columbia

Valuable stands of mature Douglas-fir in the Interior Douglas-fir Biogeoclimatic Zone of British Columbia provide a major component of mule deer winter range. As part of a comprehensive study on winter habitat selection by mule deer, an experimental timber harvesting system, designed for use on critical mule deer winter range, was tested for its compatibility with maintaining the range's carrying capacity for deer. In 1983, a 25-ha cutblock of winter range in the Knife Creek area (located in the Cariboo Forest Region) was selectively harvested with a mark-to-cut method (i.e. the selective removal of a low volume of timber, leaving the stand structure intact). Only 13% of the merchantable Douglas-fir volume was removed. Although initial deer response to the harvesting system was positive, results are still inconclusive because of the relatively mild winter of 1983/84. Furthermore, although the harvest was exceptionally well done, the mark-to-cut operation was found to be too costly. In the second phase of the study an alternative logging method — the "fallers selection" approach — was adopted to harvest three cutblocks, and the allowable volume harvest of merchantable Douglas-fir was increased to 15%. To fully familiarize the fallers with the objectives of the study and the logging criteria, a 5-page instruction booklet was given to them before they began to cut. Deer response to the harvest will be evaluated in the coming year.

H. Armleder



Diagrammatic representation of the logging criteria in mule deer winter range, contained in an instruction booklet for fallers. A detailed legend accompanies the diagram in the booklet.

Intensive Forestry Effects on Deer and Elk on Vancouver Island

On Vancouver Island, old-growth winter ranges for blacktailed deer and Roosevelt elk are rapidly being replaced by young (in some cases, unmanaged) growth. Since 1980, the Ministry of Forests and Ministry of Environment have jointly supported the IWIFR (Integrated Wildlife — Intensive Forestry Research) Program that is studying the impact of various silvicultural treatments on deer and elk habitat to find ways for the integrated production of timber and wildlife. The program has three main projects:

In one project the effects of silvicultural treatments on habitat use and populations of blacktailed deer are being investigated. Results to date show that deer have traditional patterns of seasonal habitat selection; and that in winter they use a smaller home range than in other seasons, with a preference for older second growth.

In the second project, the effects of thinning forest overstory on understory forage production is being examined in three biogeoclimatic zones — the CDFb, CWHa, and CWHb *. Preliminary results indicate four major trends in understory production: 1) the drier the site and climate, the greater the understory response, at least where salal is dominant; 2) the heavier the thinning, the greater the understory response; 3) the older the stand, the less likely that thinning will significantly increase understory; and 4) the greater the hemlock component of the stand, the lower the understory abundance and response.

The third project is examining habitat use by Roosevelt elk, especially during the winter and at calving, in the Coastal Douglas-fir and Coastal Western Hemlock Biogeoclimatic Zones in the Sayward Provincial Forest. Since 1981, research activities have been extensive: 1053 radiolocations have been obtained from 28 radio-collared elk; population characteristics were determined for four herd areas; seasonal diets were determined through fecal analysis; 11 standardized weather stations were established to provide temperature and rainfall data of various stands differing in silvicultural treatment histories; and 30 hunter-supplied animals from the study area were analyzed to determine pregnancy rates, age, and animal condition. Within the winter home range, forage availability (percent cover of species) has been studied on 556 plots and overstory density values were recorded for each of the 10 delineated habitat types. Calving habitat use was studied by radiolocating four adult cows throughout the calving season (late May to mid-June).

Preliminary results of both diet analysis and radiolocations suggest that elk winter habitat selection is influenced primarily by forage species, and secondly by habitat type. Hemlock, grasses, deer fern, twinflower, and sedges appeared to be the five major food items of the winter period, constituting approximately 80% of the elk diet. Concerning habitat types, bogs were most preferred, followed by mature timber, deciduous-conifer forest, 41- to 60-year-old forest, and 1- to 5-year-old conifer. The habitats least used were 6- to 10-year-old and 41- to 60-year-old conifer stands.

Results of monitoring calving habitat showed that sites were generally located away from valley bottoms, on benches within steep terrain.

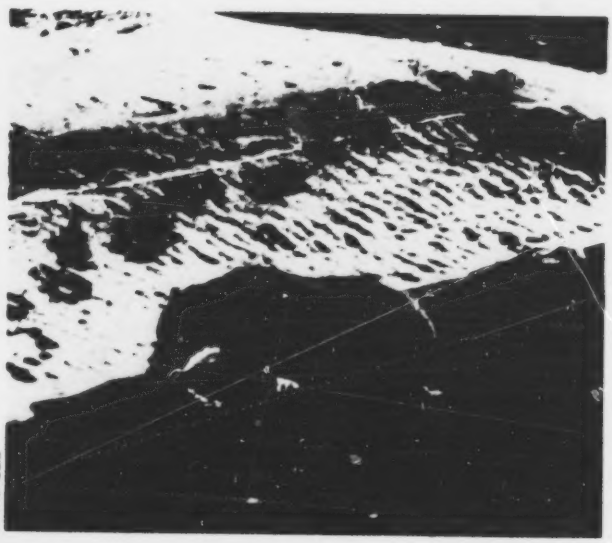
Management models for integrating forestry goals with the wildlife habitat needs described by each of these projects are now being developed.

* CDFb — Wetter Coastal Douglas-Fir Subzone
CWHa — Drier Maritime Coastal Western Hemlock Subzone
CWHb — Wetter Coastal Western Hemlock Subzone

Coastal Grizzly Bear — Forestry Interactions

Forestry development in coastal mainland watersheds of British Columbia threatens grizzly bear populations by altering their forested habitats, increasing access for sports hunters, and raising the incidence of man-bear contacts with its consequent need for "problem bear" control. Since 1982, a joint research project of the Ministry of Environment and Ministry of Forests has been examining the relationships between coastal grizzlies and their environment in the Kimsquit watershed north of Bella Coola. Its focus is primarily on determining the requirements for seasonal habitat, the impacts of different forestry practices on grizzly habitat and behaviour, and the discreteness and dispersal of grizzly populations. In addition, it is aiming to develop garbage-handling policies for wilderness camps, and information programs on the grizzly bear for personnel working in coastal watersheds.

The Prince Rupert Forest Region's recently completed ecosystem classification of the study area is serving as the basis for the description and analysis of the grizzly bear habitat.



R. Archibald

Wildlife Habitat Handbooks

Forests provide the habitat for most of British Columbia's terrestrial wildlife, and consequently, all forestry activities affect wildlife habitat. However, due to the diversity of wildlife species and the complexity and size of the forestry sector, it is difficult for forest and wildlife managers to assess the impacts on all wildlife species, and to co-ordinate management activities. To help overcome this problem, a wildlife habitat handbook project was begun in 1981 in co-operation with the Ministry of Environment, the Provincial Museum, and several universities. Based on a similar U.S. Forest Service program, the habitat handbook will organize existing life history information of wildlife species in such a way that managers will be aided in forecasting the impacts of forestry activities on habitats for all species in a study area. The Kamloops pilot project area is one of eight wildlife ecosystem regions into which the province has been divided.

FISH/FORESTRY INTERACTION PROGRAM

Since 1981 the Fish/Forestry Interaction Program has been investigating the extent and severity of landslides on the Queen Charlotte Islands, and generally assessing the effect of mass wasting on streams and forest sites. At the same time, it has sought solutions to the problems of how to log marginally stable terrain to reduce mass wasting, and how to rehabilitate streams and forest sites already affected by such failures.

A total of 13 impact and prescriptive studies have been undertaken, falling within four main areas of research: 1) watershed dynamics and the impact of landslides on the productivity of fish habitat and forest sites; 2) stream and forest rehabilitation; 3) silviculture; and 4) alternative harvesting systems. A number of the studies reported preliminary or final results in 1983/84, the highlights of which are summarized here:

- An air photo inventory of slope failures found that there is a wide regional distribution of slides over the Queen Charlotte Ranges and Skidegate Plateau. A total of 8240 slides were counted, representing a mean of 2.6 failures/km^2, ranging from 1-18/km^2.
- A second air photo inventory, examining the incidence and impact of landslides in logged and unlogged terrain, found that the natural frequency of failures is increased by a factor of 20.8 due to logging. The amount of material eroded due to failures is estimated to be 0.9 m^3/ha per year, compared to 17.4 m^3/ha per year from clearcuts. It is further estimated that 39% of this eroded material enters streams from the unlogged forest, compared to 47% from clearcuts, 66% of which is from gully failures, 12% from slope failures, and 21% from road failures.
- Studies of sediment transfer, aimed at assessing a stream's capacity to move and flush eroded material, reported that even though large amounts of material are deposited into streams by mass wasting, the steep gradient of most streams in the Queen Charlotte Islands gives them a tremendous ability to flush gravels and fine sediments from channels.
- Approximately two-thirds to three-quarters of all sediment that forms large fluvial deposits in stream channels was found to come from stream banks and landslides; and logging practices at streamside —

T. Sauder

especially felling and yarding — were determined to be the main causes of bank destabilization and erosion.

• The effects of mass wasting on resident and anadromous fish habitat suggested that such failures reduce the amount and quality of fish habitat by: reducing pool habitat 45%; reducing large organic debris 40-80%; reducing stable undercut banks 50-80%; increasing stream width 50-70%; and alienating upstream habitat. Fish population data suggest that such changes in streams directly affected by landslides can result in a loss of approximately one coho per metre of stream length, or a 33% reduction in summer rearing capacity.

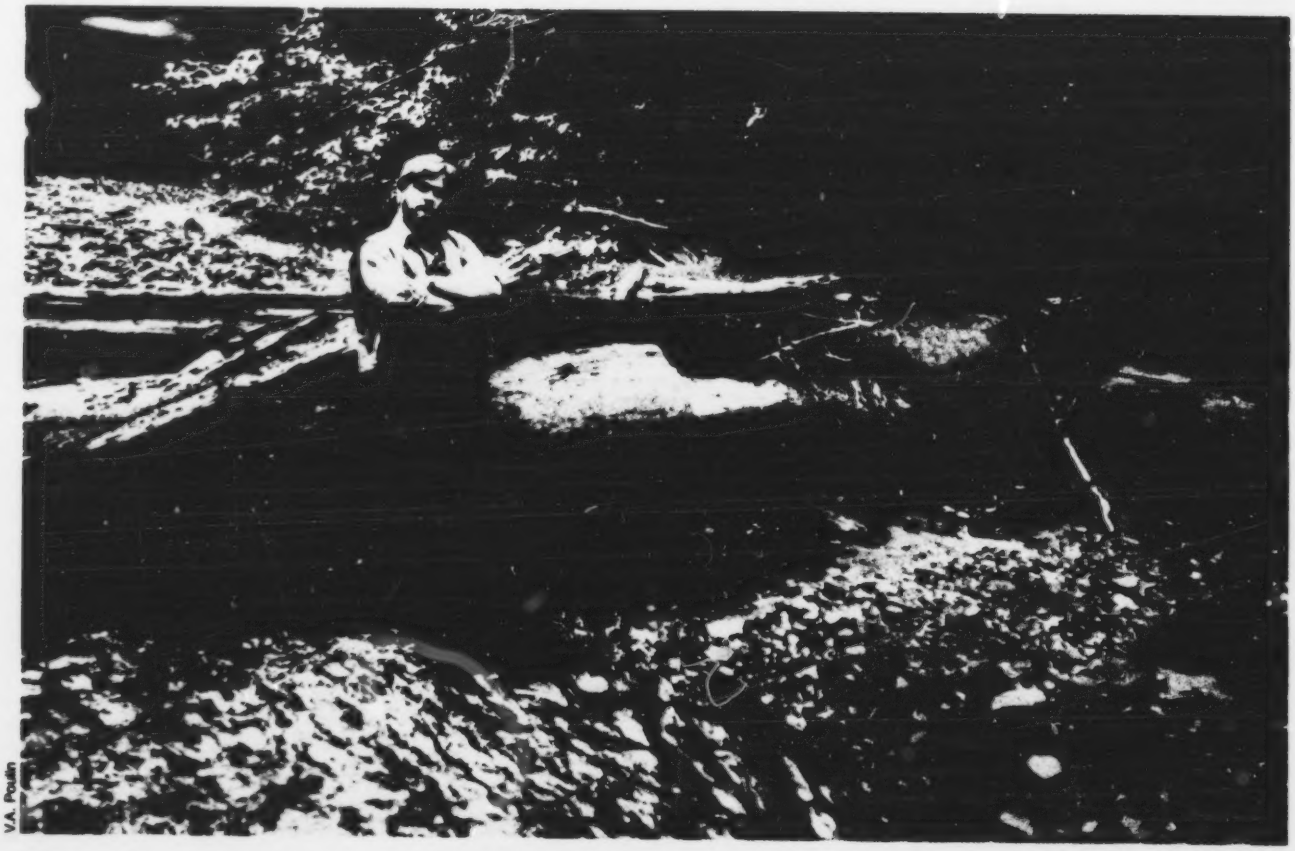
• Preliminary results of an assessment of the overwinter survival of fish in streams affected by mass wasting and gravel scour suggested that low fry numbers might be related to excessive stream scour. Egg loss attributed to the 20- to 30-cm post-winter scour depths in affected streams has been estimated at 50-95% for pink salmon, 35-85% for chum, and 15-65% for coho.

• The overall growth rate of trees on slides was found to be reduced. In a 55-year period, for example, Sitka spruce established on a slide achieved only half the height of its species growing on adjacent terrain. As well, the revegetation patterns on slides showed that although there is rapid growth on their lower one-third, growth is delayed on the upper two-thirds.

• Slides that result from logging were found to be primarily due to clearcuts, and secondly to roads. Of the clearcut failures, those that occurred in or near gullies were most significant in triggering debris torrents into streams. Of the road-related failures, most were due to lack of maintenance, although location and construction practices also contributed to the problem. The situation with the greatest potential for causing mass wasting was a road failure associated with a gully.

• Stream rehabilitation studies reported two promising methods: 1) A 1-year trial with stream-installed gabions suggested that their cost could be recovered over a 12-year period, given the apparent 3-fold increase in survival of salmon eggs which resulted; and 2) The reintroduction of organic debris into a torrented stream showed a 4-fold increase in smolt survival after 1 year.

A final report, integrating all of the information collected over the program's 5-year duration, is expected in 1985.



V.A. Poulin

ENGINEERING RESEARCH

In 1983/84, the Engineering Branch carried out a number of research projects aimed at assisting forest harvest efforts. Three of these are reported below:

Road Recorder

The road recorder is a vehicle equipped with electronic instruments for surveying forest roads. Electronic scanning equipment in the road recorder includes an odometer, vertical gradient gyro, gyro compass, and a keyboard console for recording features on the route. (A vertical gyro monitoring subsystem using an electronic inclinometer to dynamically cross-check the grade inclination of the gyro is now being developed.) Each instrument operates independently and data are presented to a micro-computer at intervals of distance specified at the control panel. Survey data are collected on magnetic tapes, and these are processed via a Forest Service terminal to the British Columbia Systems Corporation's mainframe. The software system includes programs to produce a plan and profile of each road, and shows the locations of bridges, junctions, and other features keyed in by the road recorder operator.

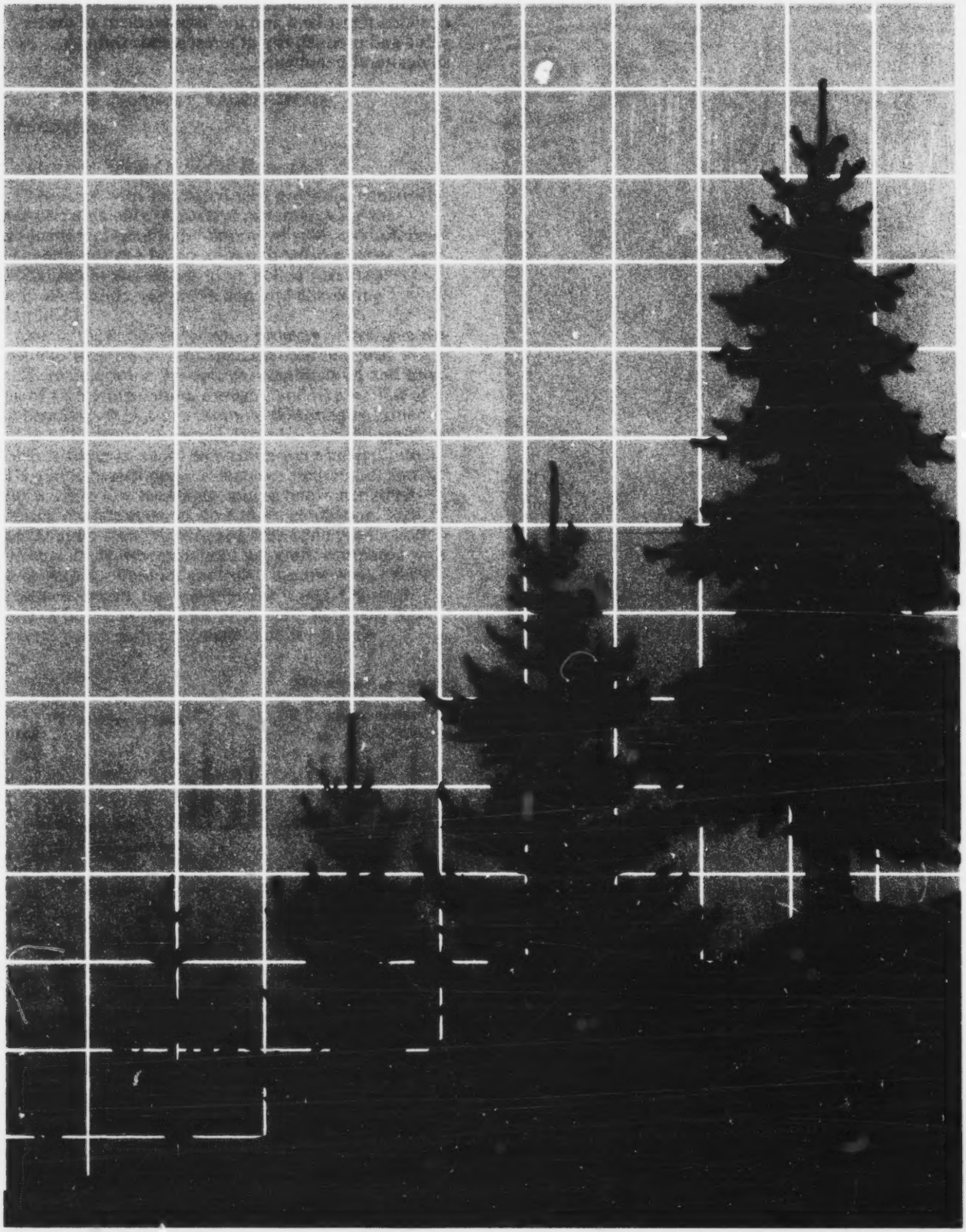
Log Haul Program

To simulate the physical and psychological processes involved in logging truck operation on forest roads, a computer model known as the log haul program was developed. It requires data on the truck (weights, gear ratios, and engine performance specifications), and on the road — data that can either come from the road recorder or from the design output of the Forest Road Design System. Program output includes empty and loaded haul times. The model adopts a semi-empirical approach to simulation: a theoretical algorithm is used to calculate potential truck performance; and empirical routines are used to regulate truck speed when the total power capabilities of the truck are not needed. These empirical routines use tables of measured truck speeds on roads (the measured speeds being functions of road grade, width, alignment, and surface conditions). Field testing has shown the model to be well within 10% of actual haul times.

Harvest Feasibility Study

The harvest feasibility system is a series of computer programs being designed as an engineering aid for foresters engaged in development studies. Given forest cover data for a particular area, and reference data on productivity and costs for engineering development and harvesting operations, the programs will allow a forester to explore the feasibility of various development alternatives. Costs of roads, dumps, and other infrastructure will be amortized against potential product values, and resource availability assessed relative to economic, technical, and environmental realities and constraints. As well, volume growth curves will enable the forester to calculate volume as a function of year of harvest.

SILVICULTURE RESEARCH



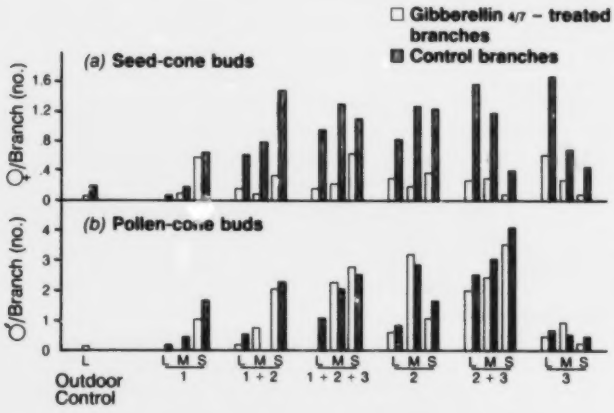
Silviculture research provides the Ministry of Forests and other government agencies with improved scientific knowledge and methods for achieving objectives in forest management, namely, the restocking of denuded forest land and the improvement of the value and productivity of forest stands through silvicultural treatments.

Seed and Nursery Operations Research

Container Seed Orchard Research

Compared with soil-based seed orchards, containerized orchards offer important advantages for the production of genetically improved seed: environmental conditions can be optimized, intensive cone-enhancement techniques used, pollen parentage controlled, and cone protection and harvesting simplified.

One in the series of research projects to evaluate the cost-effectiveness of containerized seed orchards was a study to determine the optimal combination and timing of high temperature, drought, and application of gibberellin$_{4/7}$ ($GA_{4/7}$) to promote flowering in potted grafts of Engelmann spruce. Potted 5-year-old grafts at various stages of shoot elongation were moved into a 30°C/20°C heated polyethylene-covered house, and subjected to low, moderate, and severe water stress. During the late stage of slow shoot elongation, high temperature alone maximized seed-cone production (45 cone-buds were produced per graft, compared with three each for outdoor controls), but the earlier the treatment began, the less effective it was. Optimal time of heat treatment for promoting flowering was several weeks earlier for male than for female



Female (a) and male (b) flowering responses of grafted $GA_{4/7}$-treated branches and control branches to heat treatment at different shoot elongation periods (indicated by numbers), and under different drought regimes: low, i.e. well watered (L), moderate (M), and severe (S).

flowering. Although drought inhibited the female response to favourably timed heat treatment, it enhanced flowering during early and rapid shoot elongation. The effectiveness of $GA_{4/7}$ during both rapid and slow shoot elongation suggests that both

S. Ross

drought and heat treatments increased the level of endogenous effector GA's: drought, by reducing the vegetative growth demand; and heat, by slowing the oxidative conversion of active GA's to inactive GA's and GA conjugates.

The findings show that indoor potted orchards offer several advantages over conventional soil-based orchards for enabling the rapid breeding and production of improved seed: 1) air temperature and watering can be controlled to optimize heat and drought conditions and so influence cone-bud differentiation; 2) timing of treatments can be used to promote female or male flowering selectively; 3) pollination can be hastened or delayed as desired; and 4) seeds can be collected more easily from small containerized trees than from trees grown in soil-based orchards.

In a related study, the effects of various cultural treatments (as discussed above) were compared in heated and unheated environments. The aim was to determine if the abundant flowering achieved in a heated house could be as well attained in an unheated house — one more economical to operate.

Young potted Engelmann spruce grafts were moved into either an unheated house (averaging 5ºC/1ºC above outdoor ambient day/night temperatures) or a heated polyethylene-covered house (30ºC/20ºC) for different periods of time following vegetative bud burst. All grafts were sprayed with $GA_{4/7}$. When treatment was timed to begin at 85-90% shoot elongation, the grafts flowered as profusely in the unheated house as they did in the heated one, regardless of treatment duration or watering regime. When plants were lifted and rootpruned before potting, drought had little effect on female flowering and may have inhibited male flowering. However, rootpruning and $GA_{4/7}$ appeared to interact synergistically, compensating for the lower temperatures in the unheated house. As well, cone-bud production was positively related to initial tree height, though poor flowering seemed to occur when there was either rapid or suppressed stem elongation during the treatment period. The study suggests that rootpruning or drought may promote flowering by retarding an otherwise rapid rate of shoot elongation. Because flower induction is so sensitive to the stage of stem elongation at the time of heat and $GA_{4/7}$ treatment, the study calls for a method of defining treatment time other than by calendar date or weeks since vegetative bud burst — both inadequate indicators. Monitoring stem elongation on a sample of trees is proposed, followed with treatment during stem transition from rapid to slow growth.

That early and abundant female and male flowering can be achieved in a plastic-covered house without the need for supplemental heating makes the concept of indoor potted orchards of Engelmann spruce an attractive option to conventional soil-based orchards.

Testing Seed Performance by Cold Temperature Germination

The slow and often irregular germination of white spruce seeds has made the optimal use of seed stocks at both provincial and private forest nurseries uncertain. Because normal lab germination tests do not consistently predict the performance of nursery seed, work has been proceeding with new methods for measuring seed yield efficiency. One such test, based on the use of seed developmental classes to assess seed vigour, was reported in 1982/83. This year, cold temperature germination tests for white spruce were compared to seed performance at the Surrey Nursery. Although a 10ºC/5ºC regime was found to be too cold to produce a regular or positive seed germination response, there were indications that intermediate germination test temperatures (15ºC/10ºC and 20ºC/15ºC) may provide a more reliable measure of field emergence. Tests are continuing.

Vegetative Reproduction with Cuttings

With the inherent cone-bearing difficulties of both Sitka and white spruce, seed availability of these species has been a chronic problem. Recent experiments in vegetative reproduction, however, offer not only new stock alternatives, but also possibilities for improving genetic gain. At Naka Creek, cuttings from hedges and tree-form stock plants, together with seedlings, have been planted out in small square blocks of 36 plants, and their height, stem diameter, and survival measured. An experiment with Sitka spruce cuttings from the Robertson Valley showed that the rooting in cuttings was equally promoted by a 24-hour soak in 25 or 50 ppm indole butyric acid (IBA), or a 5-second dip in 3000 ppm IBA. The effect of branch girdling on rooting ability is now being studied on material from selected white spruce grown in a progeny test at the Red Rock Nursery near Prince George.

Cold Storage Physiology of Interior Spruce Seedlings

The slow growth exhibited by white and Engelmann spruce in the years immediately after outplanting is believed to be partly the result of handling and storage procedures from nursery to field, and partly the result of adverse conditions at the planting site. In particular, cold dark storage of seedlings appears to alter important physiological functions of the plants, reducing vigour and often contributing to mortality. Improving nursery cultural practices to compensate for these conditions requires first, an understanding of cold storage effects on physiology; and second, the development of suitable measures to allow easy field evaluation of the stock.

An experiment to monitor such physiological activity was carried out with 2+0 white spruce cold-stored (-2ºC) in a bareroot seedlot at the Surrey Nursery. Root growth capacity, frost hardiness, carbohydrates, water potential, photosynthetic capacity, and amount of chlorophyll were measured every 5 weeks during the 6-month cold storage period.

Of the 31%(mg/g dw) of total food reserve carbohydrates (starches and sugars) lost during the storage period, 38, 29, and 22% were lost in the needles, stems, and roots, respectively. Tests of the effect on carbohydrate loss of storage at +2ºC and -15ºC showed that the higher temperature caused a 21% greater loss than even the 31% lost at -2ºC (increasing total loss of food reserves to over 50%); while the deep frozen storage temperature reduced total loss to only half that at -2ºC. The latter, however, had a poor rate of survival at outplanting. Although root starch levels first fell dramatically under cold storage treatment, between 5 and 15 weeks later they regained approximately 70% of their original level, demonstrating the rapid breakdown of starch into sugar, followed by a gradual rebuilding.

Throughout the storage period, root growth capacity — a critical indicator of stock quality — was very poor, with stock showing few, if any, new roots. (Earlier observations of potted seedlings have shown that at least six new roots longer than 1 cm are required within 2-3 weeks to allow seedling survival.)

Water potential of the seedlings was found to be one of the best measures of plant moisture stress, provided *both* shoot and root water potentials were measured. It was determined that predawn water potential in healthy shoots should be no greater than — 10 bars and daytime water potential no greater than — 15 bars; and that the root water potential should be at least 2 bars less negative than the shoot value.

The photosynthetic capacity of seedlings removed from cold storage in the study was low: 0.5-2.0 mg CO_2/g dry weight. Under water stress the photosynthetic rate of a white spruce seedling declined after 6 hours of exposure, and, after 24 hours of exposure, was reduced by approximately 40%.[FIG] As well, photosynthesis was very sensitive to seedlot latitude, season, and nursery cultural treatment (such as fertilization). Light saturation occurred at approximately 600 $uEm^{-2}s^{-1}$.

Linear Programing Model for Nursery Systems

A linear programing model to investigate the flow of seedlings from sowing to established plantation has been developed for the interior spruce reforestation program. Combining information about cost, nursery losses, use of nursery space, and planting stock field performance, it provides nursery managers with an aid for studying the interaction of these factors, and identifying opportunities for improving production economies.

In a recent sequence of linear program runs to show the most efficient use of nursery resources, existing nursery program assumptions were altered. Some of the preliminary findings indicate that:

- If seedling field performance was included as part of the evaluation system, then "survived seedling production" on the outplanting site would be a more appropriate goal than simply "quota seedling production" in the nursery.
- Seedlings grown in containers for longer than 1 year ("older plugs") appear to be the best of the stock type alternatives for reducing project costs while improving seedling quality.
- Expanding certain nursery facilities can result in reduced total annual costs (and hence increased efficiency). Money spent on capital projects to allow a change in production mix enabled 1983 Ministry of Forests program goals to be met for slightly more than 1982 costs, and with higher quality standards.
- Large cost savings can result from improved seedling sorting strategies in the nursery before seedling shipment.
- Improvements in data can improve decision quality.

Regeneration Research

In past years the survival rate of outplanted nursery-grown white spruce seedlings has been less than satisfactory in many of the plantations of interior British Columbia. Poor stock quality and a lack of appropriate basic and intensive silvical treatments (such as site preparation and fertilization) have generally accounted for the failed survival and inadequate growth. These in turn have imposed high additional costs on forest regeneration programs. The culmination of recent research, however, points to a turnaround in the situation. Based on pre-operational results, it is believed that the potential for consistently achieving a 90% success rate in forest establishment is now possible due to several factors: improved stock quality, through both a stock quality control system (phenotype regulation) and tree improvement (genotype regulation); site preparation; the application of slow-release fertilizers; and the use of herbicides.

Improving Forest Planting Stock

Plantation performance is governed by the interaction of the planted stock and its environment, and as such, stock phenotype (pre-adaptation to site conditions) and genotype (potential for adaptation) are key determinants of a plantation's success.

Research efforts to improve stock characteristics have demonstrated the degree to which high root growth capacity (RGC) and good root form in planting stock can improve plantation establishment and productivity. In addition to the almost 100% survival in spruce achieved with increased RGC, increases in shoot extension have been attained as well — independent of the effect of RGC on survival. With appropriate cultural regimes and handling systems in the nursery (including lifting method and date, and duration of cold storage), control of root growth and morphogenesis in all planting stock will reduce variation in stock survival and development. Other results in stock improvement studies have demonstrated that interior spruce plug stock survives and grows better than bareroot stock. Not only is survival, shoot growth, and shoot length relative to growth rate better with plug stock, but the RGC at time of planting can be as much as 8 times greater than that of bareroot stock.

Seedbed Density and Seedling Spacing

Wider spacing of seedlings in bareroot nurseries has been shown to enhance stock performance after outplanting and improve subsequent height growth and survival, particularly under such adverse site conditions as aridity or frost. It offers a simple yet effective method for increasing the quality of bareroot nursery stock.

Coastal and interior varieties of a number of species, including white spruce and Sitka spruce, were grown at a range of spacings within drills 15 cm apart, in four nurseries in coastal British Columbia. One-centimetre increases in spacing increased seedling dry weight by 0.5-1.5 g and root collar diameter by 0.2-0.25 mm, up to a spacing of 8-10 cm. With 2+0 seedlings, however, height increased little, and in some cases even decreased with wider spacing. Three years after planting, survival of white spruce increased 11% due to wider spacing in the nursery; survival of Sitka spruce increased 13% two years after planting. Widely spaced seedlings of both species maintained a height and diameter advantage over those closely spaced.

Operational precision sowing of the larger seeded species began in 1983 with the New Zealand Summit seeder. Added to next year's operations will be the sowing of smaller seeded spruce species, either by special vacuum drum fitted to the Summit seeder, or with the German Fähse Miniair small seed precision seeder.

Genetic Improvement in Interior Spruce

With the unreliable natural regeneration of interior spruce, field planting with seedlings that are genetically superior in vigour and form to those found in the wild has become a necessity.

The interior spruce program, started in 1968, is aimed at producing commercial quantities of genetically improved seed of Engelmann and white spruce. Each of the three breeding zones initially delineated (and subsequently referred to as selection units), represents an area within which climatic and ecological conditions are tolerably homogeneous. Parent trees were selected in each zone, and seed and scions collected. In 1972 and 1973, seedlings grown from the plus trees chosen in the Prince George selection unit were planted in a series of progeny tests. Similar tests were later established for the East Kootenay and Smithers selection units.

Analysis results of the 10-year height measurements from the Prince George selection unit progeny trials (174 parents) were very encouraging:

1. Significant family-related differences were apparent in progeny height, accounting for 75% of the variance.

2. Family-related height differences were detectable at an early age, so that even in the nursery several of the poorest families could be identified. The strong correlations between mean progeny heights and age are shown below:

	3-yr height	6-yr height	10-yr height
Initial height	.7763	.6644	.5863
3-yr height		.9243	.8466
6-yr height			.9560

3. Although site had a significant effect on plantation performance, the family x environment interaction was not statistically significant.

4. Heritability estimates among parent trees (family) and among individuals were 0.68 and 0.26 respectively.

Overall, the results suggest that it is possible to identify good general combiners while progenies are at an early age; and that the use of highly productive test sites and intensive plantation maintenance can increase the accuracy and confidence with which the progeny selection process is carried out.

In 1983 the breeding aboreta at the Kalamalka and Red Rock Research Stations flowered abundantly, permitting the continuation of the controlled crossing program: 210 crosses were made and a total of 272 individual pollen lots were processed and stored at -20°C. At the Red Rock clone bank, 5500 more scions were collected for the establishment of the 1.5-generation seed orchards that will supply seven seed orchard planning zones with improved interior spruce seed.

Application of Slow-Release Fertilizers

Typically, most newly planted spruce enters check, growing little for the first 5 years. Results of fertilization to offset this restraint suggest that slow-release fertilizers can improve early growth of interior spruce, provided that planting stock has a high root growth capacity and vegetative competition is reasonably low. Osmocote (17-7-12), as compared with sulphur coated urea (36.2-0-0-16.8S) and Agriform (21-10-5) was found to be best, increasing growth over the first two seasons. As well, broadcast application of the fertilizer around the stock appeared to achieve better results than did its placement in a hole 15 cm from the tree.

Effects of Prescribed Burning

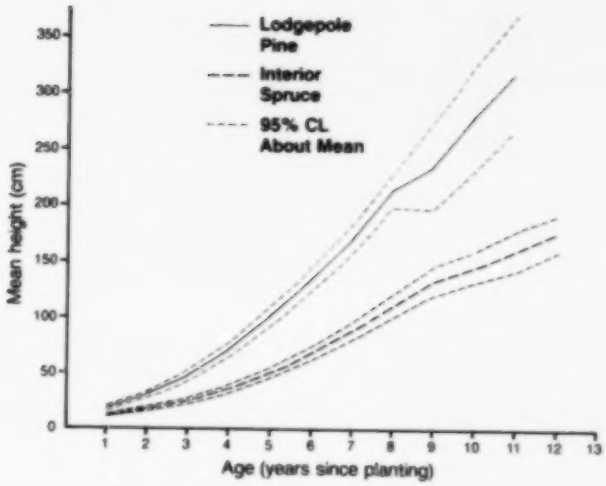
An investigation of the short- and long-term effects of prescribed fire on clearcut sites is under way in the Prince Rupert Forest Region. In 1983 two operational broadcast burning/site productivity trials were established, one each in the ESSFk and CWHg* subzones. Although poor weather prevented burning at the latter site, the results of pre- and post-fire soil analyses from SBSe** plots burned in 1982 indicated marked increases in ectorganic layer pH, exchangeable calcium, and available phosphorus. Changes in mineral soil properties, though less pronounced, showed that soil pH, total nitrogen, and especially levels of available phosphorus had increased after burning. In each of these operational trial plots, permanent vegetation sampling transects have been established to study post-fire vegetative succession. As well, to study the effects of slashburning on nutrients and tree growth in the SBSe subzone, plots established in two ecosystem types (mesic/mesotrophic and subhygric/permesotrophic) received one of three burn treatment intensities: none (control), low, or medium. Each ecosystem/treatment combination was replicated three times. Fuel loading and consumption were determined, and fuel moisture conditions monitored from a weather station installed in a cutblock adjacent to the site.

Measuring Plantation Growth Performance

A program of plantation performance assessment, related specifically to height growth, was initiated in British Columbia 10 years ago with the aim of establishing plantation performance guidelines (such as trends, curves, or standards) for forest management. Although the sampling strategy is well set out in the Regeneration Performance Assessment (RPA) survey, clear objectives, verification, and practical use of the assembled data are not so well defined.

To evaluate the type of data being provided by the RPA system, eight sets of plantation performance data gathered in the Prince George Forest Region were examined and interpreted. A total of 173 interior spruce, lodgepole pine, and Douglas-fir plantations and natural stands were included in these data sets, collected to assess stand performance in response to various cultural treatments. Analysis was limited to trend plotting plantation height/age relationships, such as that indicated in the figure. A single factor approach was used to assess the effects of cultural

* ESSFk — Northern Continental Forested Engelmann Spruce — Subalpine Fir Subzone
CWHg — Queen Charlotte Islands Coastal Western Hemlock Subzone
** SBSe — Subalpine Fir Sub-Boreal Spruce Subzone



treatment, but the data provided by the classification variables (including stock types, year of planting, and site preparation techniques) limited interpretation. It was concluded that only generalized height/age relationships could be constructed by these data, and that these could serve simply as a broad reference for local plantation assessment if no better standard than mean age performance was available. Recommendations for improving the efficiency of data collection, the quality of data, and its potential for useful interpretation are offered.

Determination of Biological Stress Relationships

In 1983/84, a series of five silvicultural research projects were established in the Prince George Forest Region by the British Columbia Ministry of Forests and the Canadian Forestry Service. The experimental series considers a variety of reforestation problems found in the SBSf* subzone on cold, wet, north-facing slopes in the Bowron River Valley. The numerous operational constraints on these sites — such as high-volume residual slash, dense competing herb and brush communities, unreliable prescribed fire windrows, and slope and soil limitations to mechanical site preparation — have raised concerns among forest managers over existing interior spruce reforestation efforts.

The trial series focusses upon a single, intensive ecophysiology experiment as the biological basis for understanding and interpreting parallel extensive silviculture trials on the same site. These latter trials consider mechanical site preparation techniques, chemical vegetation control (alone and in combination with mechanical site preparation), and prescribed fire. The process-oriented ecophysiology study provides an improved basis for evaluation of the effects of operational practice. Similarly, the extensive trial range enlarges and improves the transfer of specific biological results to operationally important sites in operationally comprehensible terms.

* SBSf — Wet Rocky Mountain Sub-Boreal Spruce Subzone

Boreal Backlog Reforestation Research

Backlog reforestation is considered an important objective in the silviculture planning of the South Peace River. The total area covered by "not sufficiently restocked" and "not commercial" cover types in the Dawson Creek Forest District alone is an estimated 50 000 ha, attributed largely to past forest fires and logging disturbance.

The pioneer seral vegetation communities that occupy most of this backlog — *Populus tremuloides, Salix* spp., *Populus balsamifera, Betula papyrifera, Calamagrostis scribneri,* and associated herbs and shrubs — are of a nature that makes successful reforestation difficult, being aggressive and as self-perpetuating after site preparation disturbance as after logging or fire. As a result, plantation success requires appropriate and well-planned preparation, planting stock prescription, and plantation maintenance.

In 1982, these requirements were incorporated into a research program aimed at developing effective backlog reforestation systems. The research site selected for study is near Stewart Lake, 50 km west of Dawson Creek, in an extensive tract of backlog forest land denuded by logging and repeated wildfire over a 20-year period. The program has focussed on operational testing of site preparation methods, aimed at determining their effectiveness in creating planter access and controlling the re-invasion of undesirable species resulting from root suckering, rhizomes, and seed. The methods used have ranged from mechanical treatments (single pass and multiple pass) to combination treatments employing mechanical, chemical, and biological techniques.

L. Herring

In 1982, four site preparation implements were tested on a variety of sites to assess each technique's feasibility. A duplex drum-chopper and a scarification plow both proved ineffective at creating planting access, mainly due to the high density of 10-year-old saplings on the site. The most effective treatment was windrowing with a piling blade. After initial windrowing, a heavy tandem disk was evaluated for soil mixing and spot preparation. An experiment to evaluate the effect of subsequent disking on plantation performance was established in October 1982.

Prompt and vigorous suckering of hardwood roots, as well as the spread of grass rhizomes, is a well-

known phenomenon in the boreal forest following all but the most severe scalping disturbances. For this reason, herbicides are being assessed as vegetation pretreatments to mechanical scarification. During the summer of 1983, an experiment to test the effectiveness of Roundup and Velpar in controlling resprouting problems was established on sites that represented the two major plant communities in the area. Herbicide applications were completed in June, followed by mechanical clearing in December 1983. In another study initiated during 1983, the role of Roundup as a dessicating agent before broadcast burning is being evaluated. Spray applications were completed in June 1983, and burning is planned for the spring of 1984.

The role of alsike clover in native grass control is also being examined. Experience in forest range studies suggests that this aggressive agricultural plant species will out-complete native grasses on adequately prepared sites, and be less detrimental to coniferous seedling growth. The impact of treatments on soil and seedling nitrogen capital will be assessed as well during the study. Planning is under way for testing additional machinery and chemical combination treatments during 1984. Information on these and the preliminary results of studies initiated in 1983 will be reported in subsequent Research Reviews.

LODGEPOLE PINE
(Pinus contorta)

The Lodgepole Pine Tree Improvement Program

The lodgepole pine provenance trials continue to provide both essential information and breeding material for what has become an extensive tree breeding program for the species. The trials, planted in 1973, were part of a study: 1) to locate the best natural stands as seed sources for reforestation in specific regions of British Columbia; 2) to establish guidelines for the movement of these seed sources in reforestation; 3) to provide materials for an anticipated breeding program; and 4) to delineate broad patterns of genetic variation.

Sixty test locations involving 153 provenances from a range-wide collection were planted in all major geoclimatic regions of the interior of the province. With the co-operation of regional research officers, scheduled assessments of growth, survival, condition, and pest and needle cast disease were conducted 1, 3, and 6 years after planting. In 1983 the 10th-year assessment (with the 13-year-old provenances) was carried out on 55 of the 60 sites — a major evaluation which has culminated in recommended changes to interior seed planning zones and seed transfer guidelines.

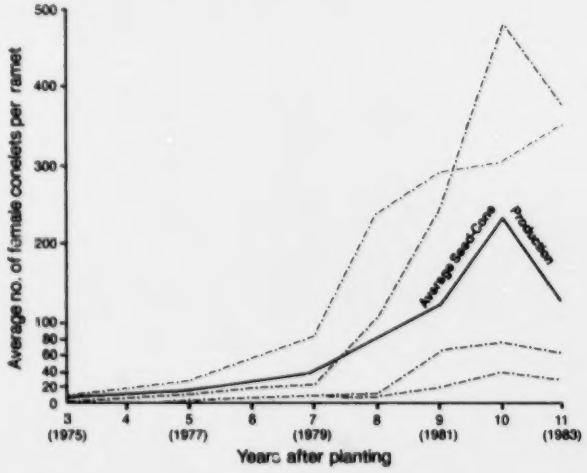
Provenance Growth

Overall, mean survival of lodgepole pine after 10 years was found to be greater than 90%, even in harsh environments. Site and provenance variables markedly affected growth. Ten-year provenance mean heights varied from 0.3-2.2 m on poor sites to 1.4-6.3 m on good sites. Of the provenances tested, those from Alberta and the interior of British Columbia grew well and suffered little cold-related damage compared with the poorer performance of populations from coastal, far northern, or far southern environments. Outstanding provenances were located along the interior wet-dry transition belt, performing best at low to mid-elevations (700-1100 m) in the central interior zone, and at low to mid-elevations (below 1400 m) in the southern interior zone.

Cone and Seed Production in Grafted Lodgepole Pine

Although cone production and seed yield in natural stands and orchards of lodgepole pine have been well studied, less is known about cone and seed yield from grafts. So that the clonal and yearly variations in seed- and pollen-cone production and seed yield could be examined, two clonebanks with grafts from 160 clones were established at the Red Rock Nursery near Prince George in 1972. Now the oldest in Canada, these lodgepole pine clonebanks offer 11-year cone production records that are expected to influence changes in the planning and design of seed orchards. In addition to revealing the complexities in the relationship between growth, flower production, and seed yield in grafted clones, the data further confirm Red Rock's suitability as a location for lodgepole pine seed orchards.

Both seed- and pollen-cone production of the grafts increased rapidly every year up to 1983, though pollen cones did not appear regularly until approximately 5 years after regular seed-cone production began.



Seed-cone production in productive vs. less productive clones.

The singular decline in 1983 is considered to have been atypical, apparently a result of adverse climate or soil nutrient deficiency. The 1982 peak in cone production, with every graft producing an average of 237 seed cones and 186 pollen clusters, resulted in a total potential of 250 000 seeds/kg. This represented 44% more seeds per cone, and seeds that were 48% heavier, than was produced by cones collected from natural stands. The large clonal variation in cone production and seed yield — a 70% among-clone variation and a 30% between-clone variation — points out the need for seed orchard managers to record the cone production capacity of individual clones to ensure that a balance will be maintained between genetic gain and seed supply during seed orchard roguing.

Wide clonal differences were also apparent in cone and seed characteristics. Correlation coefficients among cone length, width, weight, and seed content were all positive. The physiological age of the grafts did not appear to account for variations in seed yield, and the average number of seeds per cone and range of seed weight were similar to that reported for natural stands in Alberta. While high-elevation clones produced smaller and lighter cones with fewer seeds per cone than did those clones from low elevations, in terms of longitude and latitude, clones from the Yu-

kon and northern British Columbia produced larger and heavier cones with more seeds per cone than those from southern interior British Columbia.

Contrary to the usual enhancement in cone production that results from the southward transfer of grafts or seedlings, the lodgepole pine clones moved north to Red Rock produced more cones (particularly pollen cones) than did those moved south — a trend possibly explained by the generally larger size of trees from the south.

J. Murphy

Needle Cast (Lophodermella concolor) Infection

The notable increase in the past few years of needle cast in the Red Rock lodgepole pine provenance trials first prompted an investigation in 1982. Although the disease does not kill the trees, its recurrence causes premature needle shed which in turn weakens trees and makes them vulnerable to attack by other pests. Initially, trees were rated individually on an infestation scale from 0 (very light: needle cast confined to the lower half of the living crown) to 4 (very heavy: needles cast spread over two-thirds of the living crown). Since then, assessments in a number of sites in the Prince George, Cariboo, and Nelson Forest Regions — as well as at Red Rock — have been done, this time on a 9-tree plot basis rated on the following scale:

0 — none or very light
1 — less than 2 of the 9 trees heavily infested (needle cast over half of the living crown); or light infestation (confined to the lower half of the living crown) on less than half of the trees
2 — less than half of the trees in the plot heavily infested; or most of the trees lightly infested (confined to the lower half of the living crown)
3 — more than half of the trees in the plot heavily infested
4 — every tree in the plot heavily infested

Preliminary results show that site conditions and provenance are the two main factors determining the level of infestation. Sites in the interior wetbelt and valley bottoms (sites generally productive in terms of growth) are most heavily infested, while sites either at high elevations or in the drybelt (sites generally least productive) appear to be free of needle cast. Infestation among provenances varies widely, with some being virtually immune to the disease regardless of location, and others being heavily diseased even at the very lightly infested sites. The differences appear to vary in geographic patterns similar to those in which lodgepole pine growth and hardiness occur: susceptible provenances are those from the Sierra-Cascade Mountain Range, the southern Rockies, the Yukon and northwest British Columbia, and the coast-interior transition zone. Furthermore, even in the less susceptible provenances, the degree of infestation seems to vary according to elevation, with those from high elevations being less resistant than those from low elevations. This condition may be explained by the high-elevation population's previous lack of exposure to needle cast, and hence to the rigours of natural selection.

While investigations of the problem continue, advances in the genetic improvement of lodgepole pine suggest that the naturally resistant populations of this species can be further developed through breeding.

Selective Breeding Program

A program of selection, progeny testing, and breeding of lodgepole pine is now under way. Base populations have been developed for each of six or seven broad geographic zones in the province, comprising 250-300 trees each, as well as certain high-ranking provenances from different geographic areas identified by the comprehensive provenance test data. Most of these plus-tree selections have been grafted in clonebanks at Red Rock. Progeny testing began in the spring of 1983, with wind-pollinated seed from 80 Okanagan selections being sown at the Kalamalka Research Station and Seed Orchard. In the spring of 1984, these progenies were planted at five Okanagan locations, where their combining ability is now being assessed for second-generation selection. While this process continues, 20 of the same 80 selected families are being used in a trial to compare the precision of family means estimated from single-tree (non-contiguous) plots to that from four-tree (contiguous) plots across three sites. Variable spacing comparisons and "farm-field testing" of the progeny seedlings are also in progress. Another investigation is examining the effects of site, latitudinal transfer, and stock type on the reproductive biology of the species, with special reference to seed orchard siting and management.

techniques. Research in intra- and inter-provenance compatibility, inbreeding depression, and grafting and hedging methods to establish production seed orchards will complete the program.

Growth and Yield Research

Yield Prediction

The current inventory of British Columbia's forests and their projected growth rates largely determine the quantity of wood available for harvest each year. Although inventory procedures are well established, systems for forecasting yield still need to be expanded to accommodate the increasing number of managed stands. These systems depend upon permanent sample plots, site index curves, and growth models that are capable of projecting the impact of silvicultural treatments on forest stands through to harvest age.

A data base of permanent sample plots of lodgepole pine is not available in British Columbia because the species has only been of interest in recent years. Plots established since 1980 have not been remeasured and are too limited in distribution to be of immediate use. As a result, to develop growth projection systems for British Columbia, particularly for managed stands, the Ministry of Forests has relied heavily on data collected by the Alberta Forest Service and the Canadian Forestry Service. The Ministry recognizes the need for a provincial data base.

Site index curves are important components of the Ministry of Forests growth projection system because estimates of future yield are very sensitive to the accuracy of the height-age relationship characteristic of each site. New site curves were constructed for lodgepole pine from stem analysis data collected in the three western provinces by the Canadian Forestry Service, Alberta Forest Service, and the Saskatchewan Department of Tourism and Renewable Resources. A logistic growth model was fitted to the data from 188 trees. The ecological classification of the 54 trees from British Columbia suggested that the curve shape for alluvium and aralia sites is different from that of the drier cornus-moss sites. Consequently, separate equations were derived for relatively moist and dry sites.

The new site curves derived from the above procedure were used to drive the Tree and Stand Simulator (TASS-P1), which produced managed stand yield tables for lodgepole pine after being revised to overcome the limitations apparent in the first approximation tables of 1982. Data from Ministry espacement trials and other agencies were used to dampen the growth rate at older ages, improve the responsiveness of diameter to initial density, and refine the mortality routines. The tables consider a range of planting densities (2500, 1600, 1110, 750, and 500 trees/ha) and thinning intensities (1600, 1110, and 750 trees/ha) applied to a stand established naturally with 8260 trees/ha.

Periphysis in the Repression of Lodgepole Pine

With large areas of "stagnant" lodgepole pine occurring in both Alberta and British Columbia, the restoration of these stands to normal growth has become an important management concern. The operational problem of how best to improve productivity in these well-established, over-dense stands arises from their erratic height response to thinning.

One explanation for the inconsistent behaviour is that the biological mechanism controlling height response in severely repressed stands is associated with periphysis — a condition in which apical meristems after years of suppression lose the ability to respond even after environmental pressures are relieved. To investigate this possibility, an experiment was conducted in a stand of fire-origin lodgepole pine in the Prince George Forest Region, testing the hypothesis that in dense stands (those studied had between 100 000 and 800 000 stems/ha), at least 20 years old, periphysis may limit tree height response. Three treatments were tested on stagnant and vigorous trees: no top grafting (control), top grafting with scion material from vigorous trees, and top grafting with stagnant scion material. By the third growing season, reciprocal grafts of vigorous and stagnant scions on the two types of rootstock showed that growth had been entirely controlled by rootstock type: grafted onto vigorous rootstock, stagnant scions grew as well as vigorous scions; and on stagnant rootstock, vigorous scions displayed no growth superiority over stagnant scions.

Periphysis, it was concluded, is not the cause of growth stagnation. With this result, however, in addition to the strong similarity between stagnant shoots and those resulting from transplant shock, it has been suggested that differences in the form and activity of the root systems may be a potential cause of stagnation in lodgepole pine.

Thinning Lodgepole Pine with Roundup

In operational silviculture (SX) thinning experiments related to improving stand productivity in lodgepole pine, results from a herbicide treatment trial suggest that, for thinning 8-15 cm lodgepole pine, a 1 ml injection of Roundup (glyphosate) per stem will yield satisfactory mortality regardless of season, number, or plane of injections. For optimal results, spring injections to more than one site on the stem circumference were recommended.

Regeneration and Protection Research

Cone Distribution after Feller-Buncher/ Grapple-Skidder Logging

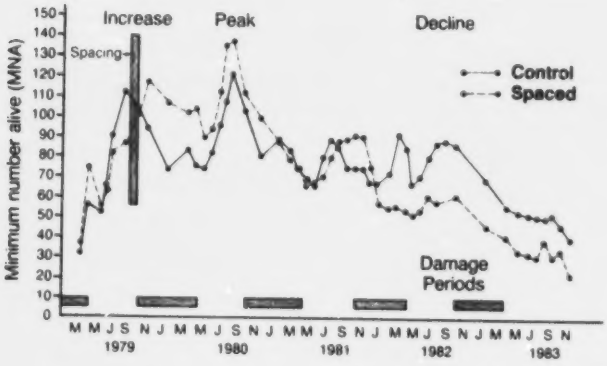
With changes in logging equipment and techniques now resulting in the more complete removal of stems and crowns from logged sites, concerns about the adequacy of seed supply for natural regeneration have been raised. A study conducted in the southern interior of British Columbia assessed the effects of a combined feller-buncher/grapple-skidder logging method on cone distribution in lodgepole pine. It found that regeneration, after this "new" method of cutting, occurred at almost the same rate as that which followed older, conventional methods (hand felling,

shears, or feller-buncher with line skidding). However, to ensure satisfactory stocking levels within 4-5 years, good quality cones in a quantity equal to 1/m² of reforestation area would have to be available on site. Leaving cone-brush slash on the cutover areas was therefore advised. Scarification, although not found to be critical to the natural regeneration on the study sites, was still recommended.

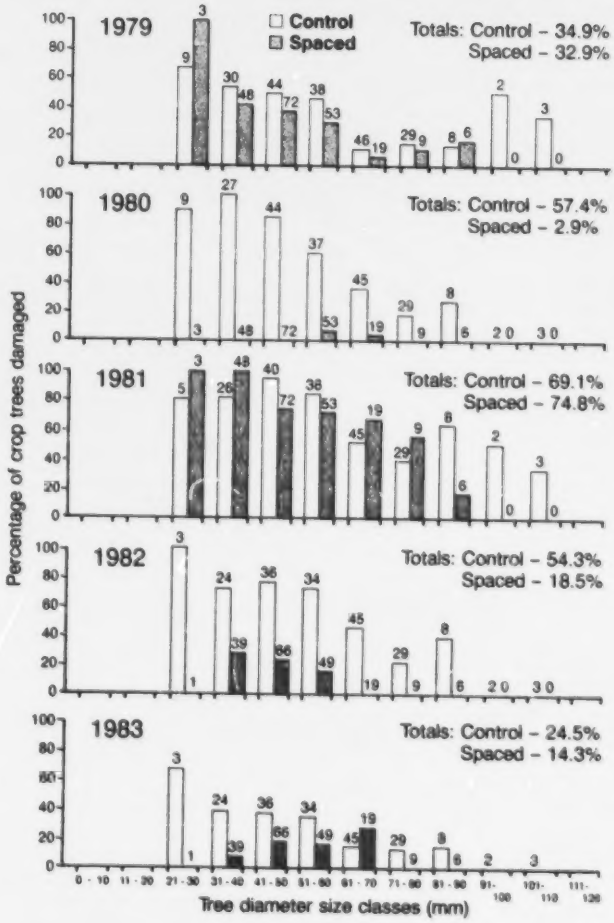
Snowshoe Hare Damage on Juvenile Lodgepole Pine

The problem of snowshoe hare feeding damage in spaced natural stands of lodgepole pine has been observed in the Cariboo, Prince George, and Prince Rupert Forest Regions for a number of years. Concern over its potential for serious future harm to commercial forests has prompted research on this forest pest.

To determine how much feeding damage individual trees can sustain before growth check or mortality occurs, a 5-year study was initiated in 1979 to correspond in time with the late increase, peak, and decline phases of the 10-year hare population cycle.



An 18-year-old stand near Prince George was manually spaced (2x2 m) and hare feeding damage and populations were monitored during five overwinter periods in this and the control stand. In the first winter after spacing (1980) only 2.9% of the crop trees were damaged. This figure increased dramatically the following winter to 74.8%, before falling to 18.5% and 14.3% during the third and fourth winters. In the same period, damage in the control stands ranged from 24.5-69.1%. Semi-girdled damage (greater than 50% tree circumference) suppressed diameter growth in both stands, but only during the first 3 years after spacing. The frequency of feeding attacks and proportion of damaged trees were notably greater for small diameter trees (less than 60 mm dbh) than for those 60-80 mm or more. Given that stands with fewer than 15 000 stems/ha generally average larger diameters, it was suggested that stands above this density are especially susceptible to hare damage. The study recommends that juvenile spacing of dense stands of lodgepole pine be delayed until the potential crop trees are greater than 60 mm diameter; and that stands with potential crop trees of an average diameter less than 60 mm be spaced during the peak or first year of decline in the hare population cycle.



Seed and Nursery Operations Research

In 1983/84, seed operation research continued with the study of various cultural practices for increasing production and collection of high-quality Douglas-fir seed. A cost-effective hormone treatment to enhance cone production and an improved technique of seed procurement were two such studies aimed at developing adequate supplies of suitable seed.

ULV Sprays for Gibberellin Application

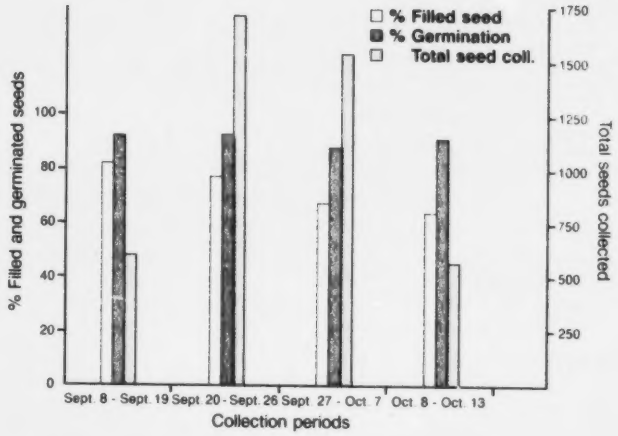
The use of ULV (ultra low volume) sprays for seed orchard application of gibberellins is currently being evaluated. Flowering responses to $GA_{4/7}$ applied by conventional mist sprayer and by ULV sprayer are being compared, and any phytotoxic effects of the adjuvant spray oils noted. Preliminary indications from an assessment of conebuds in the fall of 1983 showed that $GA_{4/7}$ applied in 2% oil by ULV sprayer was more effective than that applied by mist-sprayer without oil. No phytotoxicity from the oils occurred.

S. Ross

Collecting Seed at Natural Seedfall

To examine how collecting seed on natural seedfall dates effects seed quality, a trial was established at the Dewdney Seed Orchard in 1983. Douglas-fir cones were bagged and the seeds gathered during their natural fall between September 8 and October 13 — approximately 1 month after usual operational collection. Arranged into four test groups according to date of fall, the seeds were x-rayed and germinated to determine how many were filled and how many were germinative. As the figure shows, the percentages of both filled seeds and those that germinated was high throughout all four collection periods.

Such findings suggest that later seed collection would not only give nursery personnel some leeway in scheduling, but would also provide a yield and germination efficiency at least equal to that currently obtained in end-of-summer collections. Given the "readiness" of seed during natural seedfall, it is expected that the handling error associated with much of the soft seed in premature collections could be appreciably reduced.



Supplemental Pollination and Pollen Competition

While tree improvement programs work toward the commercial production of genetically improved stock for reforestation, there remain certain biological constraints in seed production that can limit operational seed yields, and hence the true potential for genetic gain. One technique used in the seed orchard to overcome the problem is supplemental pollination (or "boosting") — a procedure that increases seed yields while reducing contamination from foreign pollination.

In 1982 and 1983, two pollination experiments were conducted with coastal Douglas-fir to examine the "first-on, first-in" hypothesis of the pollination mechanism: that is, the first pollen to arrive on the pollination site is more likely to complete fertilization than the pollen that arrives later.

The preliminary trial, carried out in 1982, used two foreign Douglas-fir pollen parents to test the effect of a second pollination at either a 5-minute or 24-hour time interval following first pollination. In the second trial, conducted in 1983, a "self" and a foreign pollen parent were compared, this time with pollination intervals of 5 minutes, 6 hours, and 24 hours. Isozyme analysis indicated that "first-on" pollen usually did become "first-in", though its effectiveness in seed yield depended on the viability/fertility of each pollen lot used. In cases where two foreign pollen lots arrived at the stigmatic tips within 5 minutes of each other, both parents contributed to the seed produced. Where the

second pollen parent arrived 6 hours or 24 hours later, the first was in a stronger position to fertilize the ovules, though its ultimate success in seed formation depended on its viability relative to the competing pollen parent. When self pollen was applied first, seed yields were lower and the foreign pollen parent was the predominant contributor to fertilization.

Ultimately such information will help identify the optimal time for pollination in Douglas-fir, as well as provide pollen application guidelines for maximizing the effectiveness of supplemental pollination.

Mitotic Index as Physiological Indicator of Seedling Dormancy

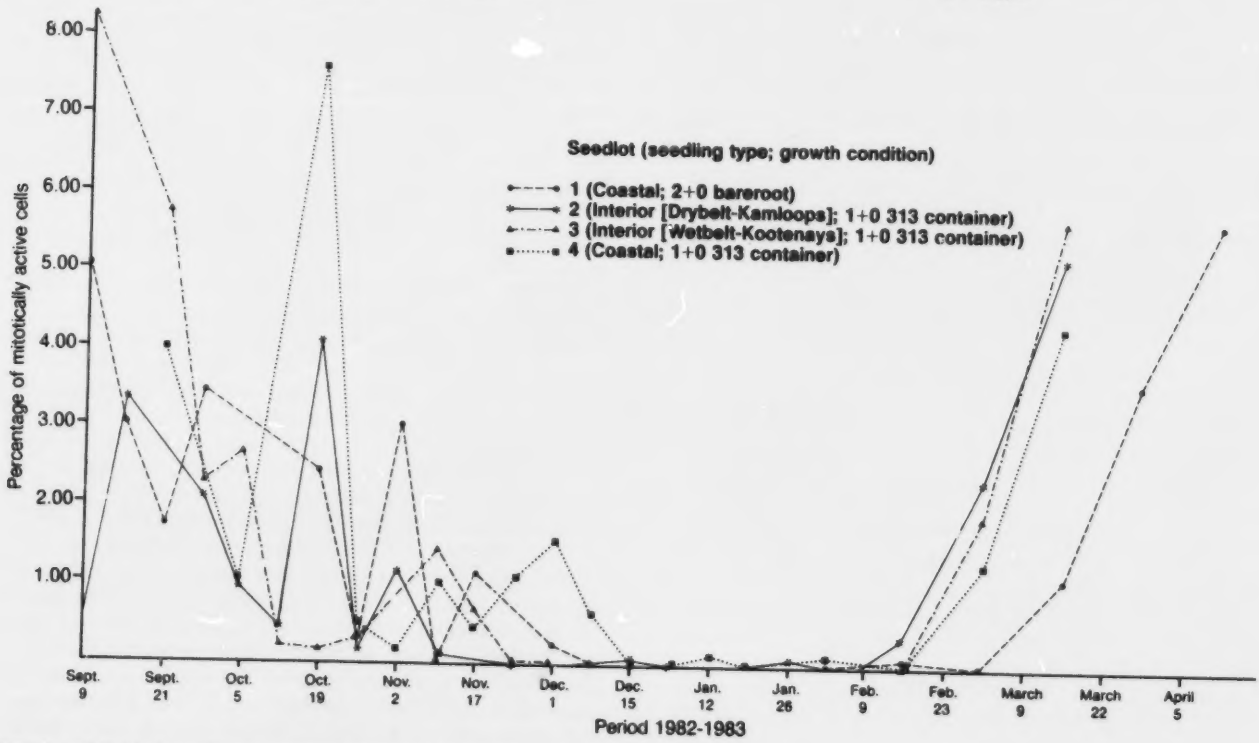
Cultural and outplanting practices that are improperly synchronized with a planting stock's physiological condition can significantly hinder growth potential — and even survival — in seedlings. Lifting and cold storage carried out at a time other than when seedlings are fully dormant can cause premature seedling flush and result in cold or frost damage to the young buds. While nursery managers are well aware of the importance of timing certain nursery activities around seedling dormancy, external inspection of seedlings cannot be used to identify this critical state, and methods to determine dormancy status are still being developed. One procedure uses the mitotic index — the percentage of dividing cells in a terminal bud — to assess biological activity in seedlings.

An investigation of the value of mitotic bud activity as a physiological indicator of "safe" fall lifting times and fall frost hardiness in seedlings began in 1982. Terminal buds on four Douglas-fir seedlots (two from the interior, containerized; and two from the coast, one containerized, the other bareroot) were sampled for mitotic activity during a 25-week period from September to March. Frost hardiness, root growth capacity, and regrowth under permissive conditions were evaluated on seven different occasions, and stock was lifted, cold stored, and outplanted.

Mitotic activity cycled slowly downward until no further activity was observed, stopping approximately 1 month earlier in the interior Douglas-fir than in the coastal Douglas-fir. At these points of minimum activity, seedling dormancy was assumed and lifting proceeded. First-year survival of seedlings lifted and stored according to mitotic activity test dates is shown in the table. Physiological activity in early spring

	Seedlot				
Lifting Date		1	2	3	4
Sept. 15	X	.667	2.00	0	.400
	S.D.	.976	0	0	.828
Oct. 6	X	.600	.733	.333	0
	S.D.	.828	.961	.724	0
Oct. 20	X	.133	.600	0	0
	S.D.	.516	.910	0	0
Nov. 3	X	0	0	0	.067
	S.D.	0	0	0	.258
Nov. 17	X	0	0	0	0
	S.D.	0	0	0	0
Dec. 1	X	0	.200	.133	0
	S.D.	0	.561	.516	0
Dec. 22	X	0	.133	0	.067
	S.D.	0	.516	0	.258

Survival Code (X_{23} seedlings) 0 = Alive and healthy
1 = Alive but unhealthy
2 = Dead



Mitotic activity during a 25-week period in terminal buds of Douglas-fir from four seedlots.

was also assessed through mitotic activity. The figure shows that cell division, once activated, increased quickly and consistently to a high level; and that container stock became active earlier than outdoor barerooted stock.

These findings suggest that use of the mitotic index to assess bud activity can provide a simple, quick method for determining safe lifting times of seedlings. The study also notes that once cell division activity has started, seedlings should not be stored at temperatures below +2°C, or even above +2°C for too many weeks.

Phosphorus Fertilization and Wider Spacing in Seedling Growth

Fertilization and spacing treatments are being closely examined in the nursery. In 1983, research continued into the mineral nutrient needs of seedlings and the optimum spacing density in seedbeds and stands.

In one study the effects of phosphorus fertilizers on growth in Douglas-fir seedlings were assessed in pots and nursery beds. Maximum growth in pots was obtained with shoot P concentrations of 0.18-0.20%; and in 1+0 nursery seedlings with 0.16%. Seedling growth was greatly restricted at a soil temperature of 5°C and an air temperature of 12°C. At soil and air temperatures of 10°C and 14°C, respectively, seedling P requirements were greater than when both temperatures were 20°C. The most effective sources of P in the nursery were monammonium phosphate, which produced the best growth in pots, and triple superphosphate. In terms of mineral uptake ability, nursery seedlings showed P recoveries of 6-11% from applied fertilizers. Although P fertilizers caused the shoot/root ratio in seedlings to increase (unlike K fertilizers, which have been shown to decrease the ratio), an improved P status increased root growth capacity in nursery seedlings and the dry weight/height ratio in potted seedlings.

In another study involving Douglas-fir, wider spacing with increased N fertilization raised the needle N% in 2+0 seedlings. As well, wide spacing raised the P% in interior Douglas-fir. Needle N% in coastal Douglas-fir showed a positive correlation with survival (r^2 = 0.24-0.35), total height (r^2 = 0.48-0.61), and current height growth (r^2 = 0.31-0.51) after 3 years in the forest. Such results indicate that enhanced outplant performance from spacing is partly due to the resultant improvement in seedling mineral nutrition.

Spacing research culminated in 1983 with the initiation of operational wide-spaced precision sowing. A New Zealand Summit seeder was used at one coastal and one interior nursery, which comprise approximately 30% of the provincial combined production of coastal and interior bareroot Douglas-fir. This operation will be extended in 1984 to all bareroot Douglas-fir and lodgepole pine, and to trials with interior spruce.

Genetics and Tree Improvement in Douglas-fir

Douglas-fir Breeding Programs

A breeding plan for interior Douglas-fir was completed in 1983, setting the basis for the tree improvement program initiated in the spring of 1982 and approved by the Interior Tree Improvement Council. The goal of the program is to produce sufficient quantities of genetically superior seed as quickly as possible, to meet the anticipated reforestation demands for the species — 20 million seedlings by the year 2000 (an increase from the approximately 8 million now being planted in interior reforestation projects). The program's concurrent production and research phases are well under way.

In accord with recommendations from an economic analysis of various seed orchard options, a breeding system comprising delayed 1.5-generation clonal orchards based on wind-pollinated progeny testing has been adopted. Broadly adapted genotypes that perform well in a variety of environments are being sought, and seven breeding zones have been proposed. Only the economically valuable traits — height and diameter growth, stem form, branch angle and thickness, and wood density — are being considered in the breeding program. Approximately 150-350 parent trees per breeding zone are to be selected and propagated for progeny testing according to the following breeding zones:

	Proposed selection	Selections made to date
North/Central Interior		
1) Central Plateau	150	150
2) Cariboo Transition	365	365
3) Mt. Robson	150	55
South Interior		
4) Shuswap/Adams	300	300
5) Mica	200	200
6) West Kootenay Low	250	250
High	200	—
7) East Kootenay	200	—

The progeny testing scheme in this program uses five to six test sites per breeding zone. To date, 15 have been located in the North/Central Interior zone and six in the Cariboo transition zone. Testing in the remaining zones is scheduled over the next 4 years. The establishment of second-generation orchards will occur after progeny tests of controlled matings among the top clones indicate best parent selection.

In the coastal Douglas-fir breeding program, maintenance, protection, and assessment of all 77 test plantations are continuing. The first selections from second-generation material were made in 1983. Crown Forest Industries, in co-operation with British Columbia Forest Products, is establishing a seed orchard for its private lands, and has made selections for it in the Ministry's provenance and progeny tests. During the next 2 years, further selections will be made by the Ministry to meet second-generation orchard needs of

the Coast Tree Improvement Council (C.T.I.C.).

Planned matings were successfully completed at Cowichan Lake Research Station in 1983, meeting the target number of 350 parent trees in the crossing program, and essentially completing this phase of the coastal Douglas-fir breeding program.

Meanwhile, with the co-operation of Washington and Oregon programs, efforts to enrich the coastal Douglas-fir breeding population with fast-growing clones and open pollinated seed are being expanded.

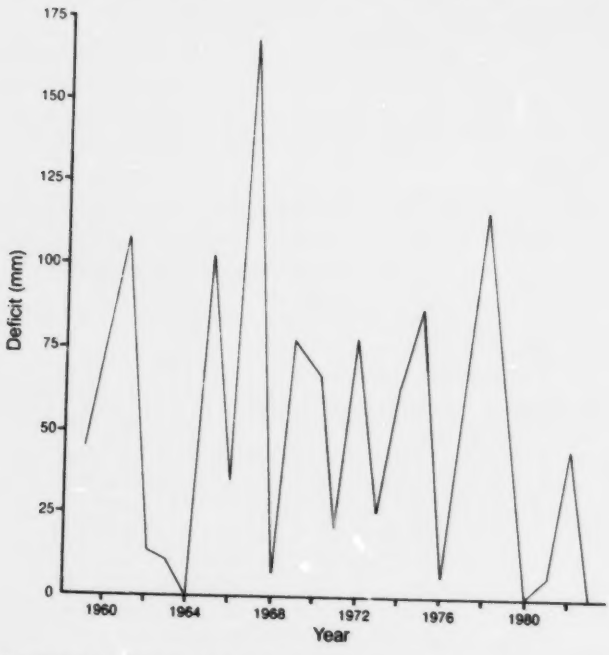
Testing Douglas-fir Rootstock Compatibility

The most compatible Douglas-fir rootstocks found in last year's testing program at the Cowichan Lake Research Station are being used both for breeding and research into scion-rootstock incompatibility. The 144 rootstock crosses that have exhibited the greatest compatibility are established in an arboretum where, to test further their degree of compatibility, they have been regrafted with scions of five or six tester clones of demonstrated high incompatibility. Final results of these trials are expected within the next 2 years, but already there are indications that the potential for mass breeding of compatible rootstocks is good and will provide an important advancement in Douglas-fir propagation programs.

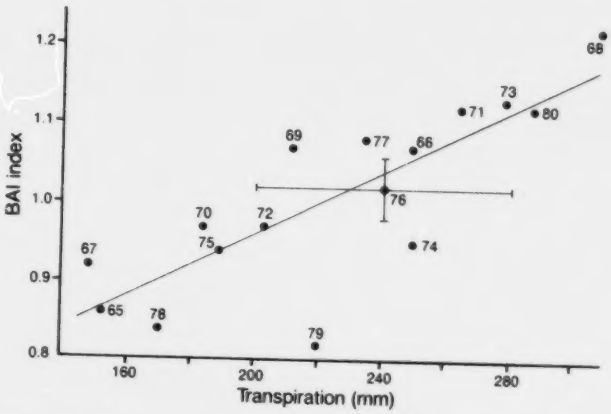
Silviculture and Harvesting Support

Forest Water Balance Models for Stand Management

In 1983/84, investigations continued into the effects of salal removal on water use, water relations, photosynthesis, and growth in young coastal Douglas-fir. In the measurement and comparison of the water balance in both a clearcut site and a forest site, the lower 0.5 m of the 0.8 m soil profile in the forest was found to be drier than that in the clearcut during the summer months. The design, construction, and testing of a micrometeorological system for measuring the flux of carbon dioxide in forest stands was also completed, and now enables the comparison of photosynthesis and weather variables over periods as short as a half hour.



Simulated annual water deficits of a Douglas-fir stand, 1959-1983. Water deficit equals the sum of daily maximum possible transpiration minus actual transpiration.



Annual basal area increment (BAI) index of a Douglas-fir stand compared to the simulated accumulated spring and summer transpiration, 1965-1980. Bars are an estimate of error. The regression line has a slope $r^2=0.667$.

In a related study, a forest water balance model was used to determine the April to October water status of a Douglas-fir stand on Vancouver Island for the period 1959-1983. Daily solar radiation, air temperature, and rainfall were the variables used. Water deficits varied from 0 to 167 mm, depending on the summer rainfall, and annual basal area increment (BAI) was closely correlated with accumulated transpiration during the spring and summer . Three sites with root zones of 0.5, 0.75, and 1.0 m were compared. Mean water deficits for the period 1965-1976 were 95, 66, and 35 mm respectively, while mean annual stand BAI were 1.1, 1.4, and 1.7 m^2ha^{-1}.

Developing Silviculture Prescriptions for Drybelt Douglas-fir

Because availability of moisture is critical to seedling survival on dry cutblocks in the Interior, competition for limited water must be controlled until a planted seedling becomes established. The effects of vegetation control and patch scarification on survival and growth of Douglas-fir were reported this year by two studies conducted in the Cariboo Forest Region.

One study, initiated in 1981, compared the effects of different types of vegetation control on Douglas-fir performance. Three treatments, with and without shading, were tested: Bracke-scarification patches, the herbicide glyphosate, and no treatment (the control). The final results three growing seasons after application show that the glyphosate spray treatment was most effective in killing and controlling the brush and

weed species on the SBSb * mesic test sites, with the beneficial results appearing in incremental and total tree heights. The greatest increment in height occurred where glyphosate was combined with shading. Spot scarification on the other hand, improved neither height growth nor survival in the seedlings when compared to the control. Shading the seedlings in their first two growing seasons improved height growth with all treatments and in all cutblocks, though it did not enhance early survival.

In a second study, the relative performance of three interior species, planted with and without prior site preparation, was assessed. Douglas-fir, with lodgepole pine and Ponderosa pine, was planted in Leno-scarified patches on three sites representing a range of hygrotopes. After two growing seasons survival in all three species had increased in the scarified patches, with the greatest increase evident on the driest site. Douglas-fir displayed the poorest survival rate of the tested species, suggesting that it is an unsatisfactory option for reforestation on dry or cold sites, or perhaps that patch scarification was not sufficient site preparation. The variable height response shown by all three species to the treatment precluded general prescriptions on its use. It is recommended that alternative methods of site preparation, such as disk trenching and furrow ripping, be tested in the IDFb ** and SBSa *** subzones, in that they might have the same benefits as patch scarification (warm soils, reduced grass competition), but fewer disadvantages (reduced organic matter, poor drainage).

Growth and Yield Research in Coastal Douglas-fir

Correlated Curve Trends

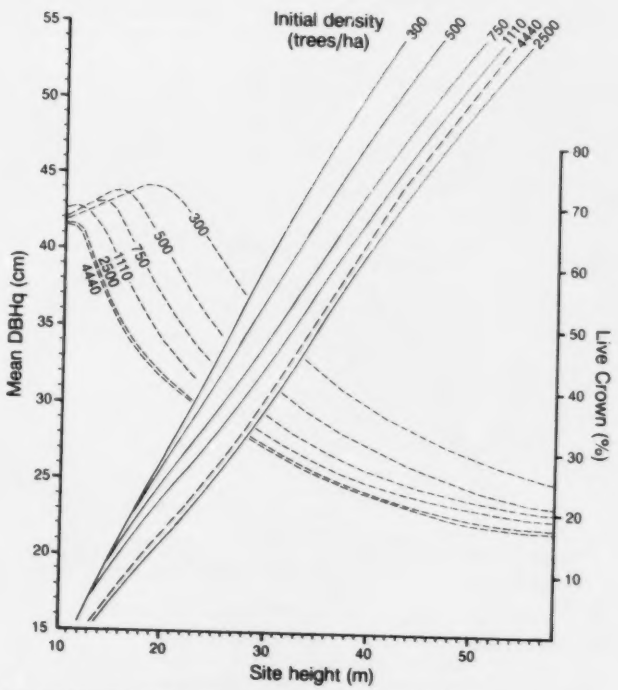
A 28-year assessment of a spacing and thinning study in a coastal Douglas-fir plantation was carried out in 1983/84, and offers important preliminary data for the development of stand management regimes. Using an experimental design based on a correlated curve trend, the study evaluated 17 plots ranging in nominal density from 3000 to 125 stems/ha. Stand average and per-hectare values were calculated by plot and age for all trees and for crop trees. Analyses indicate that, for the ranges studied, a decrease in density increased stand quadratic mean diameter (QMD), arithmetic average height (AAH), and growth in both QMD and AAH. Mortality, stand basal area, total volume and growth in stand basal area, and total volume decreased with a decrease in density. Stand merchantable volume did not appear to be affected by density, except in extremely dense stands. Prolonged early suppression seemed to hinder stand ability to respond to subsequent thinnings, as the reductions in basal area and total volume showed, but heavier thinnings seemed to produce a positive response in basal area, total volume, and QMD. Observation and measurements are continuing.

Responses to thinning at top height 23 m.

Thinning treatment	Response (%) at 23 m				
	Basal area/ha	Total volume/ha	Merch. volume/ha	Quadratic mean diameter	Average height
Light thinning (plot 13 compared to plot 3)	2.0	6.3	6.2	0.0	10.9
Heavy thinning (plot 14 compared to plot 5)	17.4	23.8	25.9	7.3	9.0
Heavy early suppression (plot 15 compared to plot 5)	11.4	15.6	17.0	9.2	6.0
Light early suppression (plot 16 compared to plot 5)	21.2	26.3	28.6	5.6	8.0

Managed Stand Yield Tables

Managed stand yield tables were completed for second-growth stands of coastal Douglas-fir, ranging from those established by natural regeneration (estimated at 4440 trees/ha) to those planted and spaced to 300, 500, 750, 1110, or 2500 trees/ha. All yield statistics were simulated by the TASS-Df model, which was calibrated with the yield of various remeasured Douglas-fir plots. Site index tables and graphs of yield relationships accompany the growth and yield tables.



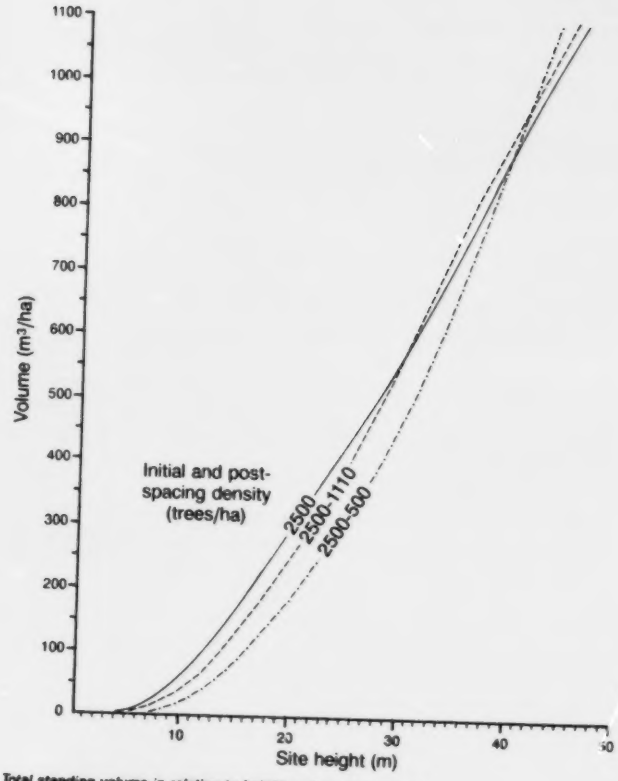
Crop tree diameter (dbhq) and live crown percent in relation to height and initial density.

(see further examples over)

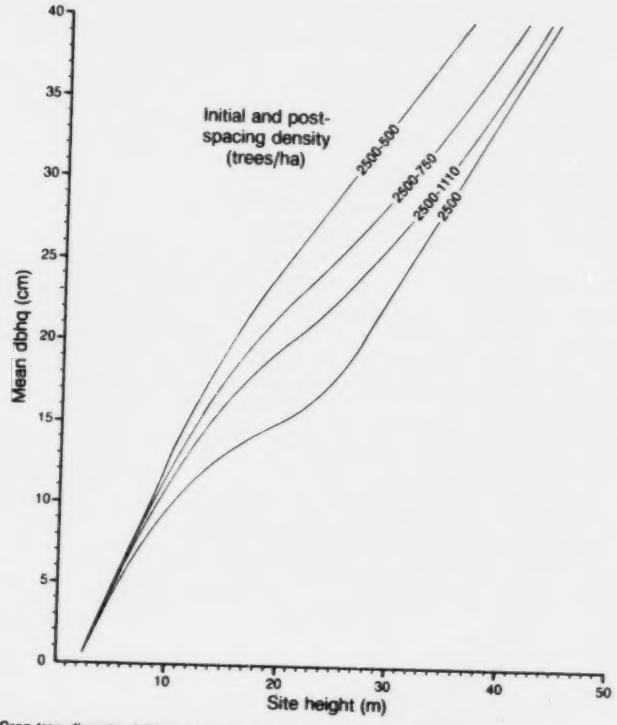
* SBSb — Dry Cool Southern Sub-Boreal Spruce Subzone

** IDFb — Very Dry Montane Interior Douglas-fir Subzone

*** SBSa — Very Dry Southern Sub-Boreal Spruce Subzone



Total standing volume in relation to height and spacing regime.



Crop tree diameter (dbhq) in relation to height and spacing regime.

Yield relationships based on managed stand yield tables of second-growth Douglas-fir.

Forest Regeneration

Fall Planting Guidelines for the Vancouver Forest Region

Although fall planting has been commonly practised for nearly two decades in the Vancouver Forest Region, its results have been inconsistent and often unsatisfactory. With the increasing demand among foresters to extend the planting season, the Ministry of Forests undertook a review of the practice to determine its relative effectiveness in plantation establishment. The review found that fall planting (end of August to the end of October) can be as successful as spring planting, provided that planting conditions are optimized. A set of guidelines to direct the operations is proposed:

- At time of planting, soil must be moist, soil temperature should be at least 4°C, air temperature should be lower than 18°C, and wind velocity should be less than 30 km/hr.
- Plug and container stock are preferable to bareroot stock, and stock quality must be high. Stock should be lifted from moist soil or watered immediately after lifting, and should not be stored.
- Planting quality must be high, and planting sites should be in the same biogeoclimatic zone as the nursery. Planting in areas with low annual snow cover (less than 50-70 cm) and soil frozen deeper than 5 cm should be avoided. Where wildlife browsing poses a problem, seedling protection is also called for.

The review further recommends that survival and growth assessments be conducted for at least 6-8 years so that the long-term effects of fall planting might be better understood.

WESTERN HEMLOCK
(Tsuga heterophylla)

Crown Management in Western Hemlock Seed Orchards

A project to develop crown management regimes for western hemlock began in 1982 with the establishment of trials to evaluate the effects of different severities of top and/or branch pruning on growth and flowering in both young and old seed orchards.

In one study, 13-year-old rooted cuttings in a clonal plantation at Cobble Hill on Vancouver Island were top-pruned to 70% or 45% of their 4-5.5 m heights (sizes that typically make cone harvesting in the upper crown difficult). Neither treatment showed any adverse effects on cone production in the following year. In fact, 2 years after treatment, the severely pruned trees (those cut more than 50% of their initial height) appeared to offer more promising results in terms of cone yield abundance than even the moderately topped trees. The dense, compact crowns of vigorous shoots achieved by the severe treatment are expected to be especially productive in the coming years, and suggest that both long-term height control (to aid harvesting and supplemental pollination) and redirected lateral shoot growth (to enhance seed yields) can be attained by such crown management.

The Western Hemlock Breeding Program

As a result of the 1981 review of the western hemlock breeding program, breeding was started for a restricted area (the West Vancouver Island, North Vancouver Island, and Johnstone Strait zones) with cone-induction techniques applied to potted ramets of a reduced breeding population. The first crosses were conducted in 1983, with more planned for 1984. Preliminary results indicate that sufficient filled seeds were obtained for all crosses attempted.

Support studies have been in progress. A 12-tree diallel test, for detecting genetic control over features of interest to progeny assessment for second-generation selection, was measured at age 2 years in the nursery. Analysis of these data indicated predominant genetic control, although there were also some reciprocal effects, implying that early measurements may be biased. As well, a 10-tree half-diallel that incorporated a 6-tree complete diallel was planted at two sites on southern Vancouver Island in the spring of 1984.

Regeneration Performance Assessment

In a study to assess the early performance and suitability of species not generally used for artificial regeneration in the Kamloops Forest Region, western hemlock's 5-year performance compared favourably with that of Douglas-fir, Engelmann spruce, and lodgepole pine planted at similar elevations within major biogeoclimatic zones. Performance was particularly enhanced when seedlings were planted on moist — not wet — loamy sands, relatively free of heavy herbaceous or deciduous cover. The study concluded that western hemlock should be considered an acceptable species for planting in the ICHm* and ICHw** subzones.

		Average total height [1] (cm) after five years					
Zone	Elevation (m)	Western hemlock PSB 211	Douglas-fir 2+0 BR	Engelmann spruce PSB 211	Engelmann spruce 2+0 BR	Engelmann spruce 2+1 BR	Lodgepole pine PSB 211
ICH	<800	89	97	90	85	105	79[2]
ICH	>800	59	70	58	55	52	83
ESSF-*	>800	29	N/D	44	44	44	68
ICH**							

1) *Heights for species other than hemlock derived from Regeneration Performance Assessment, with data from 5 or more plantations each species and stock class.*
2) *One plantation only.*
* *ICH – Interior Cedar – Hemlock Zone*
** *ESSF –Engelmann Spruce – Sub-Boreal Fir Zone*

* ICHm — Moist Central Interior Cedar — Hemlock Subzone
** ICHw — Western Wet Submontane Interior Cedar — Hemlock Subzone

WESTERN REDCEDAR
(Thuja plicata)

Pelleting Tree Seed to Improve Precision and Efficiency in Sowing

The use of pelleted seeds in bareroot and container nurseries offers substantial benefits: increased sowing precision, more uniform seedling densities, reduced waste, and cost savings from mechanical sowing. Investigations of the effects of pelleting on seed stratification and germination have continued to show favourable results.

Last year 50 000 pelleted seeds of western redcedar were sown in a semi-operational trial at the Koksilah Nursery in Duncan. The germination rate for both pelleted and unpelleted seeds was approximately 85%, indicating few, if any, problems with non-disintegrating pelleted seeds. In the spring of 1983, the experiment was carried to a greater scale with the sowing of 500 000 pelleted seeds. Again operations proved successful. Although pelleted seeds were initially slower to begin germination than were unpelleted seeds, six weeks after being sown both seed types exhibited comparable stages of germination. At the end of the growing season there were still no differences in seedling growth between the treated and untreated seeds. The implications of these results for improving the labour efficiency of Ministry of Forests operations are significant.

Effect of Deer Browsing on Early Growth of Conifers

Five-year height and survival data were collected from pure and mixed plantations of redcedar, western hemlock, and Sitka spruce on the Queen Charlotte Islands. It was found that unguarded western redcedar seedlings were heavily damaged by deer browsing, but that the use of browse guards substantially increased both its survival and height growth. By comparison, browse guards did not greatly increase either survival or height growth of western hemlock. Browse damage was minor even on unguarded Sitka spruce seedlings.

As shown by the table, Sitka spruce had the best survival rate and height growth, little harmed by browse damage. Western hemlock height growth was close to that of Sitka spruce, but its survival was significantly lower. Western redcedar height growth was notably below that of the other species, and its survival only as good as western hemlock's. There was no indication that either height growth or survival of the three species was changed by planting in either pure or mixed treatment plots.

These early findings suggest that unless steps are taken to protect western redcedar plantations from such intense browsing pressure, the species will face potential demise as a major forest component in this region. As a result, even on sites ecologically suited for cedar, Sitka spruce and western hemlock may become the only viable species for reforestation.

Browse class* and location	Species and guarding: Sitka spruce** Guarded (%)	Sitka spruce** Unguarded (%)	Western hemlock Guarded (%)	Western hemlock Unguarded (%)	Western redcedar Guarded (%)	Western redcedar Unguarded (%)
None:						
Sewell Inlet	–	67.7	46.8	42.0	13.5	0.6
Lyell Island	–	65.6	78.0	77.3	21.4	12.5
Sewell and Lyell	–	66.8	60.9	55.8	16.9	5.4
Less than 25%:						
Sewell Inlet	–	29.0	49.0	47.0	44.1	3.4
Lyell Island	–	26.9	22.0	19.5	49.4	14.2
Sewell and Lyell	–	28.1	36.8	36.3	46.3	7.8
25-75%:						
Sewell Inlet	–	3.1	3.5	10.5	35.8	29.1
Lyell Island	–	7.4	0.0	2.3	21.4	19.2
Sewell and Lyell	–	5.0	1.9	7.3	29.7	25.1
Greater than 75%:						
Sewell Inlet	–	0.1	0.7	0.5	6.6	66.9
Lyell Island	–	0.1	0.0	0.8	7.7	54.2
Sewell and Lyell	–	0.1	0.4	0.6	7.1	61.7

* *Browse class is the percent of current growth (1982) that was browsed.*

** *All guards were removed from the spruce during the 1979 assessment.*

TRUE FIRS

(Abies lasiocarpa, Abies amabilis, Abies procera, Abies grandis)

Improving Seed Performance

Investigations of tree seed dormancy and poor germination continued in 1983/84, aimed at developing techniques to improve seed performance and facilitate operational implementation. The redry pretreatment, tested in previous years, consistently increased germination in amabilis fir seeds, although the effectiveness of the procedure appeared to diminish with time. This year's pretreatment research focussed on the effects of temperature on germination in stratified and redried fir seeds, based on evidence that seed performance is enhanced by low temperatures. Two *Abies amabilis* seedlots — one that received normal stratification, and the other redrying — were germinated in one of three environments: a growth chamber at 10°C/20°C; a greenhouse at 20°C constant; and an incubator at 30°C/20°C. Preliminary results indicate that *Abies* seeds can germinate at cool temperatures with little loss of overall capacity, though there may be some sacrifice in the rate of germination.

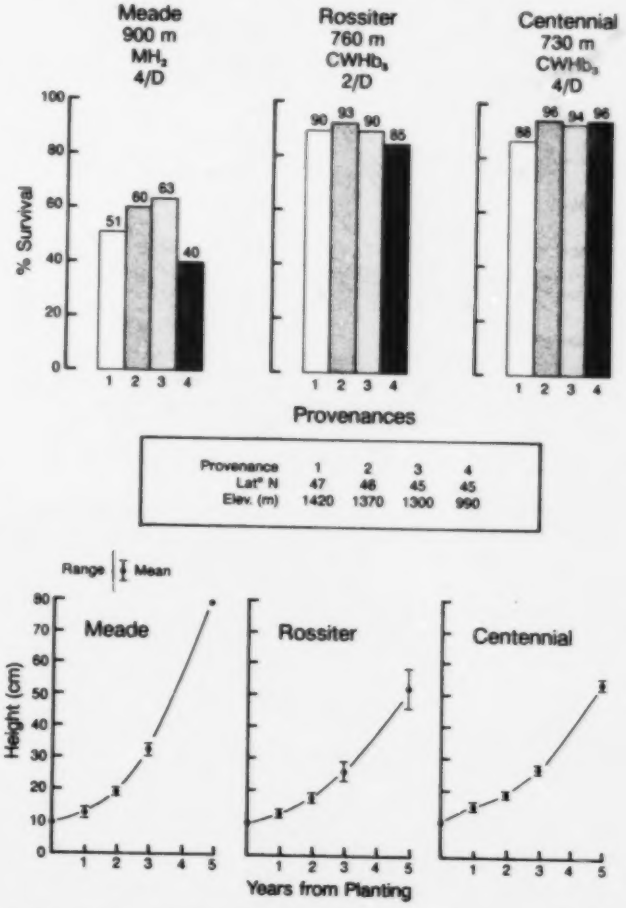
Paralleling these experiments has been the development of two new drying procedures: one using a microwave oven to allow quick moisture content measurement, and the other a rotary tumbler to dry operational quantities of seed. In 1984, the design and construction of the latter was refined such that a number of seedlots can now be dried simultaneously and seeds can be easily removed during the process for moisture content assessment. The resulting multiple-compartment tumbler-drier is expected to be widely adopted in both research lab and nursery.

As part of the commitment to rapid and efficient dissemination of new research findings like this, more than 20 professional consultations and workshops on seed performance, treatments, and technology were conducted by Ministry of Forests personnel during the year.

Performance of Noble Fir in High-Elevation Species and Stock Type Trials

In 1974, a program to advance methods of high-elevation artificial regeneration was undertaken in co-operation with the Canadian Forestry Service with the objectives of: 1) improving the nursery phase for the production of stock for high-elevation reforestation; and 2) identifying species, provenances, and stock types suitable for high-elevation reforestation when natural regeneration fails. The first test areas selected for these trials were in the montane western hemlock and mountain hemlock biogeoclimatic subzones of Vancouver Island. In addition to amabilis fir and Noble fir, other species planted in various trials established between 1975 and 1980 included Douglas-fir, mountain hemlock, western white pine, and yellow-cedar.

In the first trials of Noble fir, four provenances grown as styroplugs were fall-planted at three test sites. After five growing seasons, high survival and good growth were obtained on the montane western hemlock sites (CWH), but survival was poor on the mountain hemlock site (MH) due to insufficient hardiness of the stock at the time of planting. In an adjoining trial established at the same time to compare the true firs with Douglas-fir, mountain hemlock, and yellow-cedar, amabilis fir showed the lowest growth rate of all the five species tested in contrast to Noble fir that showed one of the best.

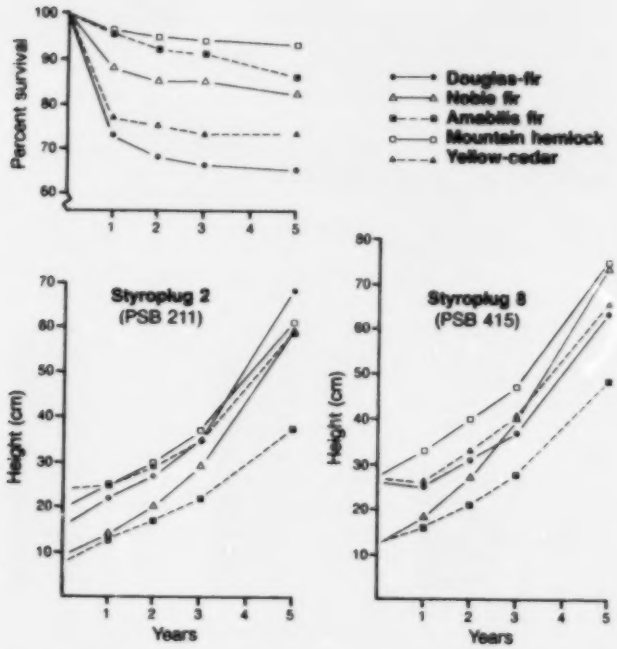


Fifth-year survival and average height growth of four provenances of Noble fir at three test sites.

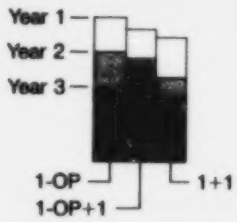
In the latest series of trials, the survival and growth of the true firs, mountain hemlock, and yellow-cedar were assessed according to stock type used during fall and spring planting. For the true firs, plug and plug transplant stock gave the best survival and growth

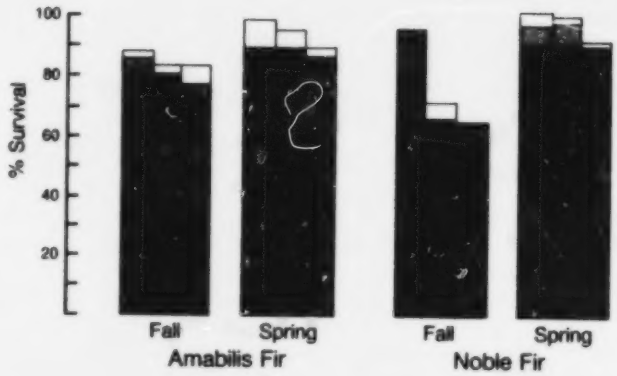
rate. Spring planting was more favourable than fall planting, particularly for the bareroot and plug transplant stock of Noble fir.

Such promising results suggest that Noble fir may be a suitable species for reforesting cutovers in the montane western hemlock subzones of southwestern British Columbia. Nevertheless, caution should be exercised when this species is selected for outplanting in the mountain hemlock subzones until further research results are available.

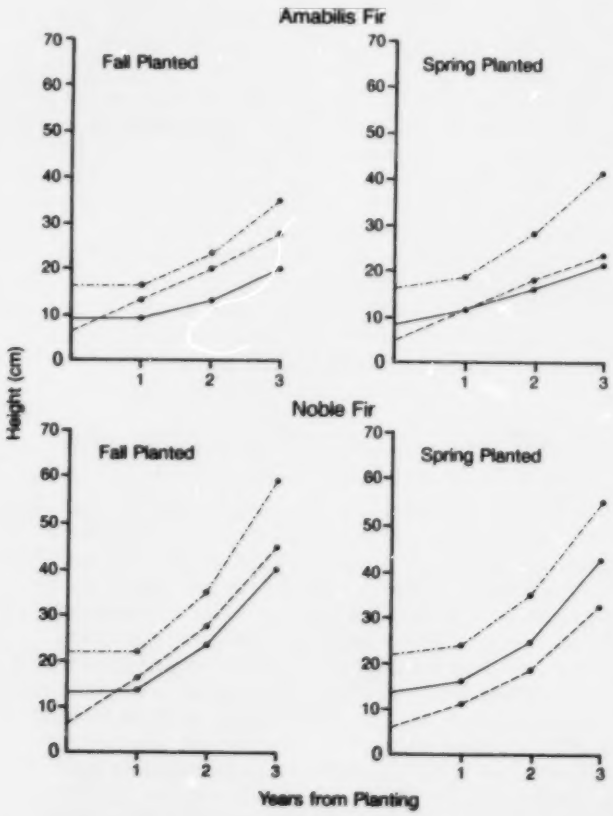


Percent survival and seedling height of five species outplanted at Meade Creek and Rossiter in fall 1975 and 1976.





Percent survival of three stock types of amabilis fir and Noble fir outplanted in the fall and spring 1978/79 at Meade Creek.



Seedling height of three stock types of amabilis fir and Noble fir outplanted in the fall and spring 1978/79 at Meade Creek.

Effects of Initial Spacing on Growth and Development

In each of the three study blocks (Falkland, Rock Creek, and Cherry Creek) 2+0 yellow pine seedlings had been planted during the Fall of 1962 and the Spring of 1963 in plots with initial square spacings of 1.22, 2.44, 3.66, 4.88, and 6.10 m.

A number of problems inherent in the study prevented a comprehensive analysis of the data. However, a cursory evaluation revealed that although spacing did not affect mean tree height, location did. Mean diameter on the other hand, was significantly affected by both location and spacing, and increased with increasing spacing. Significant differences in mean tree volume were attributable to location and not to spacing but neither location nor spacing significantly affected volume per hectare. The lack of an observed relationship between spacing and mean tree or per hectare volumes may be partly due to the erratic response of diameter and height both within and between sites.

YELLOW CEDAR
(Chamaecyparis nootkatensis)

Hedging Orchard Research

Yellow-cedar is in demand for reforestation in high-elevation areas, yet nurseries have generally been unable to meet seedling requirements because of the species' limited cone yields and poor seed performance. The successful propagation of yellow-cedar by rooted cuttings at the Cowichan Lake Research Station (reported in 1982/83 Research Review) showed that this method offers a satisfactory alternative to seedlings for meeting planting stock needs. The subsequent development of a hedging orchard to provide material for the mass production of cuttings prompted an investigation of the effects of hedge maturation on cutting vigour. To this end, each family row in the hedging orchard has been cut and maintained at three height levels — 25 cm, 50 cm, and 1 m, with one free-growing control left. Rejuvenation and growth performance of cuttings taken from the different levels is now being assessed. A separate nursery study is examining the effects of hedge age on cutting growth.

In addition to the yellow-cedar research carried out at Cowichan Lake in 1983/84, the facility produced 100 000 yellow-cedar cuttings for the Silviculture Program's production needs, using material from the hedging orchard.

I. Karlsson

THE ECOSYSTEM CLASSIFICATION PROGRAM

Nearly 10 years ago the Ministry of Forests (then the British Columbia Forest Service) set out to systematically classify the major ecosystems of the province's forest and range lands, and further, to develop resource interpretations of these ecosystem units to guide management decisions. Now, with almost two-thirds of the province's ecosystems sampled and mapped, the program's integration into Ministry of Forests policy and application to resource management are well under way.

Purpose

The ecosystem classification program is based on the concepts of philosophy on the biogeoclimatic classification system developed by Dr. Vladimir Krajina, a plant ecologist at the University of British Columbia. This system classifies the province into broad geographical areas (biogeoclimatic zones, subzones, and variants), according to their unique climate, soils, and vegetation. Ecosystem classification provides the link to the biogeoclimatic units by characterizing the major ecosystems within each, and describing the structure, function, and interrelationships that distinguish them. It is this comprehensive organization of information, accompanied by specific resource management interpretations, that is now providing forest and range managers with a solid framework within which to make well-informed site-specific management decisions. For example: the ecosystem classification can guide a silviculturist in deciding what species to plant on what site, and what site treatment to use where and when. Not only does this promote successful reforestation and productive growth, it also aims to maximize quality and quantity of wood yields without harming the environment. That ecosystem classification can provide an integrated approach to *all* aspects of natural resource management — water, soil, timber, range, wildlife, and recreation — suggests that it offers scientists and resource managers alike one of the best planning and management tools now available.

Each of the province's six Forest Regions has been responsible for carrying out the program in its area. Some of this work has been conducted by industry and Section 88-sponsored consultants in co-operation with Ministry of Forests' personnel. Field sampling and analysis are nearly complete in most parts of the province, as is the organization of the assembled information and production of reference material. This has involved the preparation of field guides, biogeoclimatic unit maps, operational manuals, and plant guides for ecosystem identification. (In 1983/84, for example, the Prince George Forest Region produced 12 guides to the different ecosystems in its region.) Plans for mapping at an ecosystem level are also in progress and, to ensure consistency in the accuracy and quality of the ecosystem maps produced, pilot projects have been initiated to standardize the mapping procedures. To date such projects have been carried out at three sites: Pimpernel Creek, the Sayward Forest, and the Truax Basin.

With much of the basic work in setting up the program now accomplished, the major emphasis in all forest regions is being shifted to teaching management and operational staff how to use the classification system. Each forest region conducts numerous training sessions every year. Participants learn to appreciate the necessity for an ecological approach to management. They learn how to identify important vegetation, site, and soil factors; how to identify the ecosystem unit; and how to make appropriate management decisions given the forest, range, and wildlife interpretations specifically developed for each ecosystem.

Applications

The ecological classification system has a broad range of applications, although its use in British Columbia up to now has been mainly in silviculture. In addition to guiding site classification, tree species selection, and site preparation, the system can be applied in **forestry** to determine seedling stock and fertilization requirements, optimum growth and yield objectives, potential stand productivity, potential site productivity, and best season to harvest. It is currently providing Silviculture Branch with a framework for pre-harvest assessment and site history records, and Protection Branch with ecological information for evaluating fire-fighting priorities in northern British Columbia.

In **wildlife and range** management, ecological classification can be used to assess biomass production; to delineate habitat areas critical to wildlife survival; and to determine ecosystem carrying capacities and suitable stocking rates. In **conservation** it can provide a basis for the selection of candidate areas for ecological reserves, by identifying unique or threatened ecosystems and those with outstanding characteristics relating to forestry. To **recreation** it offers guidelines for recreational land use assessment and the development of interpretive programs.

Other applications include **planning** (where it can be used to weigh land use allocation alternatives); **research** (where it can focus research efforts where they are needed, as identified by ecological interpretations and distribution of ecosystems); and **engineering** (where it can provide critical site and soil information).

Implementation

Although still in the early stages of implementation, ecosystem classification is gradually being incorporated into Ministry of Forests policy and routinely consulted in research projects and forestry operations. For example, a standard symbols and codes list for all

plant species in the province, seed zone maps, and the degradation policy are some of the ways the classification has been adopted. In addition, many research studies have used an ecological approach:

• The moisture/nutrient regimes which characterize ecosystems are now being related to forest stand nutritional data to aid identification of stand fertilization. requirements. In the Prince Rupert Forest Region, foliar analysis is being tested as a means for determining nutrient status in four coastal tree species, and this in turn is being related to type of landform and parent material on a site-specific basis.

• Two fire-ecology studies completed this year in northern British Columbia demonstrated how an ecological approach to priorizing fire control efforts might be implemented. Knowledge of forest ecosystem processes and the relative productivity of sites was incorporated with information about the role of fire and its effects on specific forest vegetations within the biogeoclimatic zones of the Fort Nelson and Cassiar TSA's. Both investigations showed that such information, combined with clearly defined land use objectives, can refine existing fire management guidelines by identifying areas where fire suppression is high priority, and those where prescribed burning is recommended.

• In the Prince Rupert Forest Region the effects of fire on forest production are being documented on an ecosystem-specific basis in a series of prescribed fire ecology studies. (See "Interior Spruce", page 16.) Data on fuel, soil, and seedling growth are being analyzed within the context of ecosystem classification.

• As part of the Kimsquit Valley coastal grizzly research project being conducted by the Ministry of Environment and the Ministry of Forests (discussed in "Wildlife Habitat Research", page 6), ecosystem classification and mapping of the area is assisting researchers in their analyses and interpretations of the grizzly bear habitat.

Meanwhile, modifications and refinements to the system continue. For example, because of the hygrotope classes presently described in the ecosystem classification are assessed on a relative scale within each biogeoclimatic subzone, the actual moisture status of the same hygrotope in two distinct subzones can be different. In the Vancouver Forest Region, an absolute scale of hygrotopes is being developed based on the quantification of soil moisture content regimes. As well, the ecological classification of grasslands is in progress, to be included in the overall program in the near future.

Province-wide classification and correlation of all the ecosystem data are to be completed within 3-5 years, at which time the program is expected to be fully embodied in Ministry of Forests policies, planning, and practices and in standard use throughout the forest industry.

Composition and environmental properties summary for the Northern Boreal White and Black Spruce Subzone, Fort Nelson TSA

Ecosystem Mosaic	Dominant Association	Minor Association	Terrain	Forest Productivity[1]	Fire[2]	Fire Control Priority[3]	Fire Control Measures
1	B1	B3, B2	Dry Mineral = L.C.	Good C.L.I. 3-5	Spring: mosaic burns due to fuel variation ranging from Sw-moss to aspen-shrub-herb. Spring fires may be driven into Sw from adjacent Sb stands. Summer: resists fire in summer.	High	Fire lines OK in mineral, good trafficability
3	B3	B1	Wet organic–shallow to deep permafrost	Very poor C.L.I. 7	Spring and summer: mosaic burns due to fuel variation and high rates of spread. Many unburned islands.	Very low	Fire lines problematic in organic terrain
2	complex of B1, B2, B3		Dry mineral–wet organic mosaic	Complex of mosaics #1 and 3	Spring: mosaic burns due to great fuel diversity. Spring fires often driven into Sw or SwAt mixes from interfingered more flammable Sb stands. Summer: B2 and B3 burned preferentially; Association B1 resists fire.	Medium	Interfingering of associations strongly complicates fire line construction
5	B2	B3	Wet mineral with shallow peaty surface	Poor C.L.I. 6-5	Spring and summer: relatively uniform burns, very few unburned islands. High spread rates.	Low	Fire lines OK in mineral, moderate trafficability due to wetness in B2
4	complex of B2 and B1		Dry mineral–wet mineral mosaic	Complex of mosaics #1 and 5	Spring: mosaic burns due to fuel diversity. Fire often driven into Sw or SwAt from interfingered Sb stands. Summer: B2 burned preferentially; Association B1 resists fire.	Medium	
6	Alluvial Sw	seral Cot. and willow	Dry mineral, subject to inundation	Excellent C.L.I. 2-3	Very rare.	High	

[1]Forest productivity ratings are estimates only, no productivity plots were undertaken in this project. (C.L.I. = Canada Land Inventory)

[2]Forests of Mosaics 1 to 5 have developed under the repeated influence of fire, typically long return interval crown fires. Evidence of fire is present throughout.

[3]Fire Control priority ratings consider only the relative intrinsic value of the mosaic to produce fibre.

Watershed Rehabilitation Operations for Forested Slopes

A review of prevention and rehabilitation techniques for erosion control in Queen Charlotte Island watersheds was completed in 1983/84 — a research project conducted under the Fish/Forestry Interaction Program (see page 8). It emphasized that if forestry operations are to continue on the area's marginally stable terrain, foresters will have to adopt road building and timber harvesting techniques that can halt soil erosion, minimize downstream impacts, and restore watershed integrity. It recommended a number of such techniques for immediate use on the Queen Charlotte Islands:

Prevention techniques

For open-slope erosion: rapid root growth of residual vegetation should be promoted (by fertilization, for example); and the abundance of fast-growing rehabilitation shrub species be ensured through seeding or planting. (See "Native Shrub Propagation" below.)

For road-related erosion: revegetation, the installation of buffer strips to minimize downslope sediment movement, and proper road maintenance — such as sufficient drainage and proper road closure after use — should be carried out. (See "Roadside Erosion Control through Hydroseeding" below.)

Rehabilitation techniques

To restore erosion-damaged landscape, a three-phase bioengineering approach should be adopted, involving:

1. technical or mechanical preparation of the site, with slope rounding or contouring, construction of terraces and berms, and/or the use of fibre netting materials.

2. selection of revegetation techniques. For herbaceous vegetation the two techniques suitable for use on the Queen Charlotte Islands are dry seeding and hydroseeding. For woody vegetation there are three options: direct seed sowing; planting unrooted, hardwood cuttings; or planting rooted seedlings.

3. selection of plant material: herbaceous or woody depending on the site conditions.

Roadside Erosion Control Through Hydroseeding

Hydroseeding research has two main objectives: 1) to find effective and practical ways of controlling surface erosion on exposed slopes and on other failures related to forest harvesting; and 2) to prevent the subsequent escalation of surface soil movement to a state of mass soil erosion. In a report summarizing the forest roadside revegetation research of Ministry of Forests, the success of hydroseeding in achieving erosion control at a range of roadside test sites suggests that these objectives are being well met. The results, measured over 5-8 year periods, show hydroseeding's potential effectiveness for vegetation establishment at most sites.

S. Hornoky

A number of guidelines for optimizing its successful application are given:

- Drought-tolerant grasses should be included in the seed mixes to be applied to dry sites and/or problem soil types.
- Alfalfa is best suited to interior sites; sainfoin to coastal sites.
- Slope revegetation and grazing are incompatible.
- Cutslope formations must be eliminated or prevented to forestall erosion.

Hydroseeded sites located in all six Forest Regions continue to be monitored at 2- to 3-year intervals and refertilized if necessary. The information these sites provide is regularly relayed to operations personnel in both the public and private sectors through training sessions, consultations, and semi-operational seeding.

Native Shrub Propagation: Users Guide

A preliminary guide to woody plant species for use in land rehabilitation in British Columbia was completed in 1983/84. The 26 species were selected according to three major criteria:

1. the known biological and ecological characteristics of each candidate species
2. performance in field trials
3. performance in propagation trials.

The guide includes procedures for four types of propagation: seed, hardwood cutting, softwood cutting, and root cutting.

FOREST VEGETATION MANAGEMENT IN BRITISH COLUMBIA

Problem Analysis Completed

Competition from undesirable plants can greatly reduce growth and survival of crop trees. In recent years the problem has been addressed in a program known as vegetation management — the science of manipulating vegetation and the micro-environment to achieve desired vegetation production. Forest vegetation management affects all phases of stand development, from harvest and site preparation to seedling establishment and intensive silvicultural treatment; and in this it recognizes a broad range of vegetation control methods, including appropriate choice of harvest system, immediate reforestation, suitable planting stock, prescribed fire, mechanical and manual site preparation, mulches or cover crops, grazing, and herbicides.

In 1983/84, a comprehensive problem analysis identified and discussed the vegetation management research needs for British Columbia. Nineteen complexes of potential problem vegetation were singled out — eight dominated by hardwoods or conifers, six by shrub vegetation, and five by herbaceous species. The study found that despite existing management efforts in the province, problem vegetation is increasing annually, with weed vegetation, in particular, threatening commercial tree yields on many sites. It concluded that the key to reversing this trend lies in research, training, and education. Ten research goals were identified as priorities:

- establishment of screening trials;
- study of the effects of site preparation and harvesting methods;
- study of the effects of weed removal timing on crop tree growth;
- study of the influence of species composition in non-commercial vegetation;
- development of operational methods for assessing competing vegetation;
- study of the environmental impacts of herbicides and alternative treatments;
- incorporation of vegetation influence evaluations (4) into stock type trials;
- identification of environmental factors limiting crop tree growth in the major biogeoclimatic zones;
- study of autecology of major competitors;
- development of a system for classifying and predicting seral vegetation.

The need for vegetation management specialists on staff at Ministry of Forests was called for, as was the training of forestry personnel — technicians, practising foresters, and forestry students — in vegetation management objectives, value, and application.

The report is being extensively supported by follow-up studies and field trials in the Vancouver, Cariboo, Prince George, and Prince Rupert Forest Regions. While research to develop stress-resistant, rapid-growing planting stock continues, other projects are investigating site stress reduction and techniques for controlling vegetative competition. The project list includes: herbicide and prescribed fire trials; studies of hotplanting and post-burn planting delays; experiments with the use of large planting stock and grass/legume cover crops; and trials examining the biological effectiveness of mechanical site preparation equipment.

Operational Trials

Results from several silviculture operational trials (SX trials) were reported in 1983/84. In one, a John Deere 450 crawler tractor and an FMC 220 flex-track tractor were used to operationally test the effectiveness of conventional mechanical site preparations on steep terrain. The trial found that the FMC tractor offered several advantages over the conventional crawler tractor: good performance even on very steep (75-80%) terrain; superior traction and stability; and overall high efficiency at comparatively low cost.

In another trial, the growth response of interior spruce seedlings to release by broadcast herbicide treatment was examined. Over the 2-year trial, total vegetation cover in the treatment block — broadcast sprayed with the herbicide Roundup (glyphosate) — was substantially reduced, especially in the first post-treatment year. Futhermore, during the three growing seasons of the trial, mean growth of seedlings was significantly higher in the treated area (40.45 cm) than in the control area (35.34 cm).

A trial to test the effectiveness of various herbicide treatments in salal control found that the herbicides Garlon 4 (triclopyr), Roundup (glyphosate), and Tordon 22K (picloram) did not adequately control salal when applied at rates varying between 500 and 2500 g a.i./ha. The report concluded that until further herbicide testing is conducted, slashburning remains the most effective method for controlling salal.

Standard protocols to guide forest vegetation control trials and operational treatment monitoring are now being developed so that treatments can be evaluated comparatively. The inclusion of seral vegetation in the biogeoclimatic classification system is further expected to aid forest managers in designing harvest and reforestation strategies that will reduce or avoid problems with competing vegetation.

Engineering Research

In 1983/84, the Engineering Branch continued to provide extensive support to Silviculture Branch with a number of research projects:

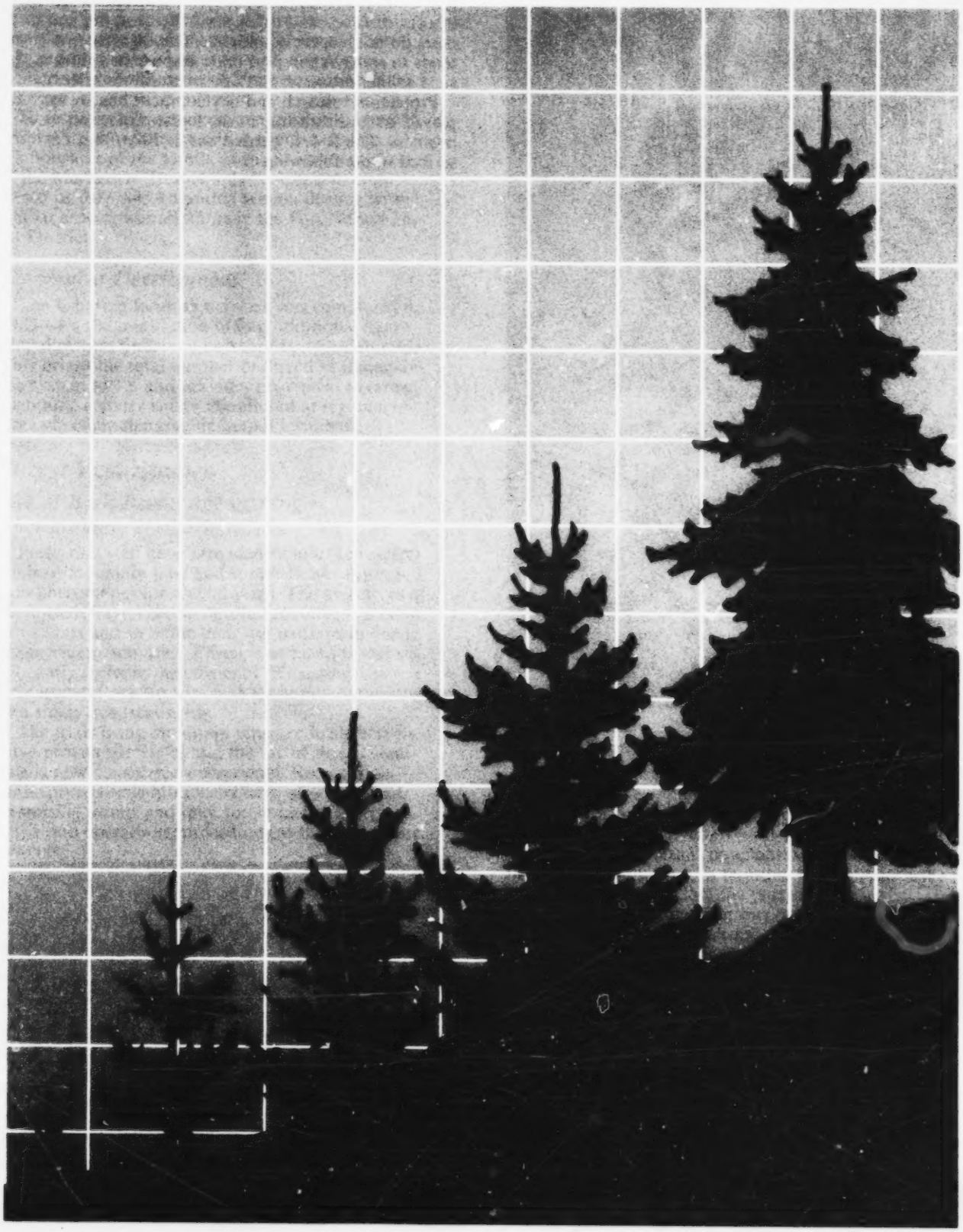
- Trials using herbicide attachments for brush saws

were initiated, evaluating the efficiency of the method for brush control;

- Field testing of the Cat D7 tractor/hydraulic ripper spot scarifier for reforestation site preparation (designed by Engineering staff and reported in 1982/83) was carried out near Prince George and at the Surrey Nursery;
- Assessment of stump and root pulling equipment for use on logged root-rot infested sites was begun, with selected equipment to be tested in the Prince George Forest Region and at an appropriate site on the coast;
- A radio-controlled helicopter equipped with a ULV (ultra low volume) sprayer head for herbicide application in brush control was prepared, and is ready for field trials in 1985.

In operations research, Engineering Branch continued its detailed time studies of site preparation equipment, begun in 1981. The resulting productivity information is being used by Silviculture Branch to evaluate site preparation costs submitted under licensee research projects — Section 88(2). Time studies of road construction equipment, carried out during the summers of 1982 and 1983, are now being included in the Engineering Manual estimating guide and used by Valuation Branch.

PROTECTION RESEARCH



The basic objective of Forest Protection is to cost-effectively implement the prevention and control measures which minimize losses to the provincial forest and range resources caused by wildfires, forest insects, diseases, and other pests. Because fire and pests do not respect boundaries, this objective extends to some extent into other important values such as life, property, and other natural resources.

Protection research and development has always played a significant role in the forest protection business. The R & D carried out in 1983/84 is described in the following.

Fire Studies

Reports Available

Guidelines for prescribed fire monitoring procedures are being prepared for publication, and will incorporate minimum standards for the pre-, during, and post-burn phases. As well, a system to evaluate the effectiveness of forest protection is under way.

To assist with fire management planning in northern regions, a report describing the fire-ecological relationships of the forests in the northern portion of the Mackenzie Timber Supply Area was completed in 1983/84. A training session dealing with similar aspects was also held in the Fort Nelson Forest District.

Equipment Development

The lightning location network was completed in 1983 with the installation of four additional lightning direction finders in northern British Columbia. This brings the total number of direction finders on the system to 15, and provides provincial coverage. Lightning activity is now monitored at regional offices via computer graphic output terminals.

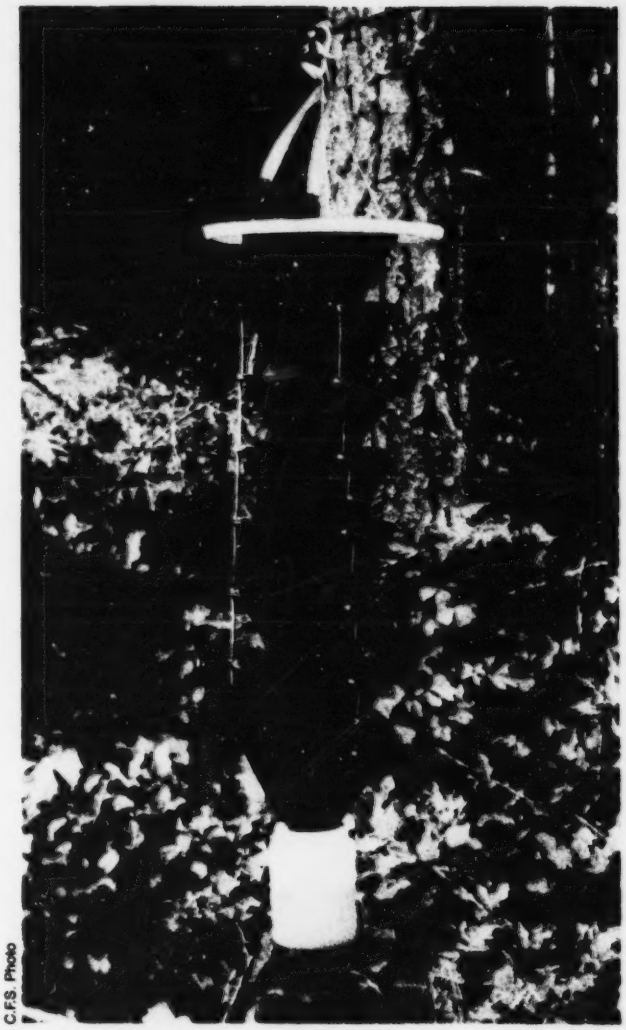
Forest Pest Studies

Use of Bark Beetle Aggregating Pheromones

Protection staff have provided support to research trials of mountain pine and spruce beetle aggregation pheromones for several years. The objectives of these trials have been to develop effective synthetic attractants and to refine their use patterns in beetle management activities. Effective attractants will significantly increase the efficiency of existing management practices such as sanitation harvesting and single tree treatments.

The trials using mountain pine beetle attractants have proven successful and the use of these chemicals is now considered operational. Recent trials with spruce beetle attractants have also produced promising results and they, too, may be incorporated into operational procedures in the near future.

C.F.S. Photo

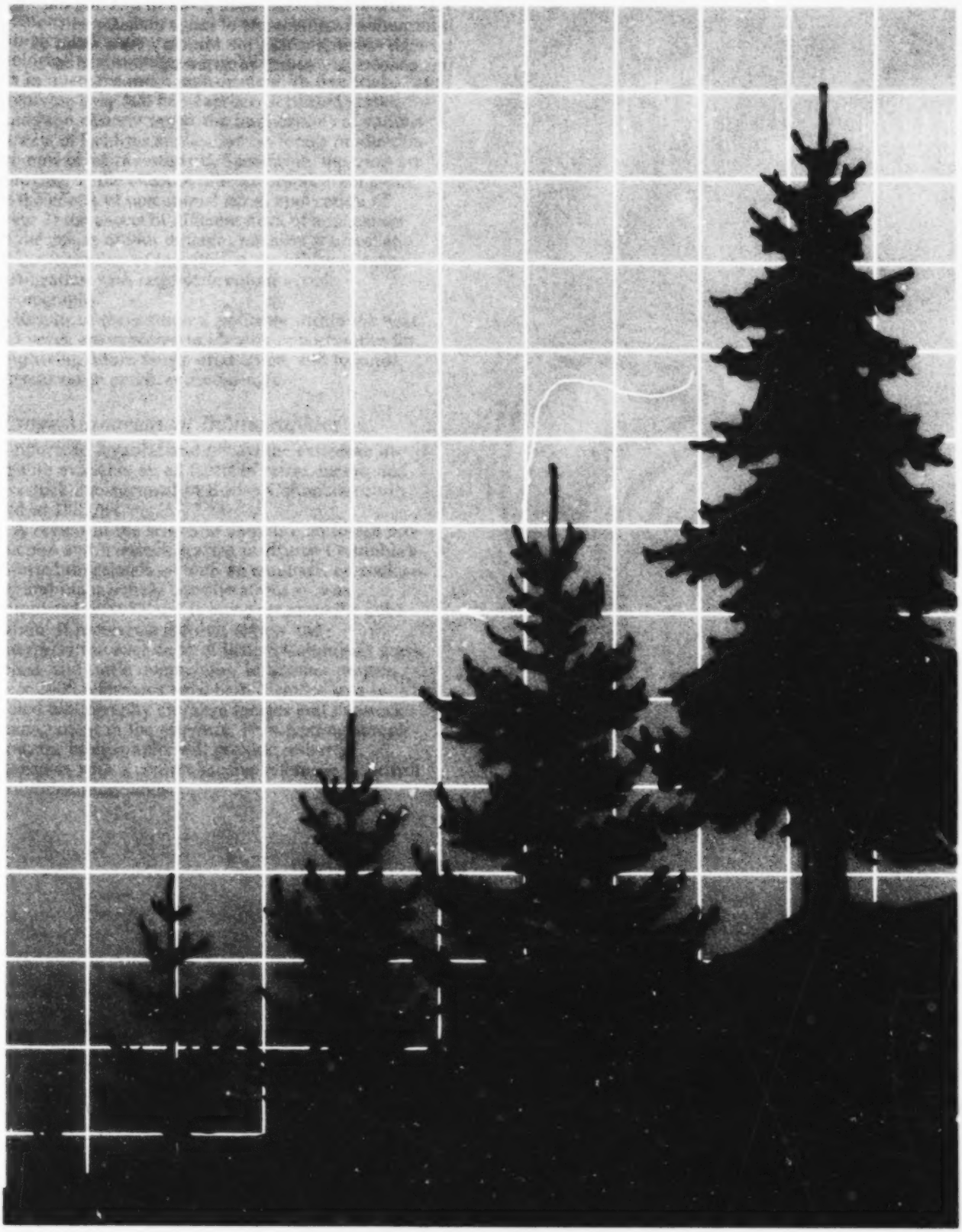


C.F.S. Photo

Second-Growth Pests

A study has recently been carried out in the Prince George Timber Supply Area to determine the type and level of incidence of pests in second growth spruce forests. Plantations over 10 years old were sampled and the most important potential pest problem identified was *Pissodes strobi*, a terminal weevil. Although weevil incidence was low, the potential for adverse impact on spruce regeneration was recognized. Further surveys and impact studies are needed to monitor and assess plantation problems.

RANGE RESEARCH



The Ministry of Forests has been responsible for the jurisdiction of Crown ranges since the Grazing Act of 1919 became effective. Subsequent to the Act, very little attention has been given to meeting the information requirements of range management through research within the Ministry. As a result of this concern, a research program was initiated in 1981.

Biological and Economic Effects of Range Fertilization

Since 1981, the long-term Range Fertilization Demonstration Project has been gathering field samples and analyzing data in its aim to assess the biological and economic feasibility of using fertilizers in intensive range management. In five trials, involving over 500 ha of aerially fertilized grasslands and clearcut range, the implications of various aspects of fertilizer application on forage production are now being investigated. Specifically the trials are studying: 1) the effect of different application dates; 2) the effects of operational aerial application of urea; 3) the effects of different rates of application; 4) the effects of four different nitrogen sources; and 5) the feasibility of monitoring the effects of range fertilization with large-scale colour aerial photography.

Results of these studies, available within the next 2-3 years, are expected to identify opportunities for improving future forage production, and to guide current range practices accordingly.

Range Management Bibliographies

Efforts to organize and review the extensive literature available on all facets of range, forage, and livestock management in British Columbia continued in 1983/84.

A review of the scientific literature on forage production and livestock grazing in British Columbia's forested rangelands — with an emphasis on ecological and management considerations — was completed in 1983 and is being prepared for publication. It represents the first review and interpretation ever done of British Columbia's grass, forest, and cattle interactions. In another project, over 1400 references have been included in a selected bibliography on range forages and livestock management in the province. Now nearing completion, the bibliography will provide resource managers with a comprehensive reference to British Columbia rangelands.

LIST OF ACTIVE EXPERIMENTAL PROJECTS

1983-84 RESEARCH PUBLICATIONS

EMPLOYEES OF THE MINISTRY OF FORESTS, RESEARCH BRANCH

LIST OF ACTIVE EXPERIMENTAL PROJECTS

E.P. 62, 63, 64, 66, 283
Successive thinnings in a natural stand of Douglas-fir
S.A.Y. Omule

E.P. 204, 205, 499
Thinning and pruning demonstration plots
S.A.Y. Omule

E.P. 364
Commercial thinning study in Coastal Douglas-fir
S.A.Y. Omule

E.P. 365
Thinning study in Coastal Douglas-fir
S.A.Y. Omule

E.P. 368
Adaptability of tree species to sites
S.A.Y. Omule

E.P. 370
Partial cutting in the Columbia Forest Zone
C.F. Thompson

E.P. 384, 385
Thinning experiments in lodgepole pine, Canal Flats
C.F. Thompson

E.P. 388
Commercial thinnings in western hemlock, East Thurlow Island
S.A.Y. Omule

E.P 418, 469, 554
Correlated curve trend studies in Coastal Douglas-fir
S.A.Y. Omule

E.P. 429
Spacing trials of pure and mixed stands
S.A.Y. Omule

E.P. 474
Inbreeding and sterility studies with Douglas-fir, Cowichan Lake
F.C.H. Yeh

E.P. 479
Plus tree selection and registration of Douglas-fir
J.C. Heaman

E.P. 502
Planting trials in the Prince Rupert Forest Region
J. Pollack

E.P. 511
Crop-tree thinning of western larch Perry Creek, East Kootenay
C.F. Thompson

E.P. 513
Racial crosses with Douglas-fir
J.C. Heaman

E.P. 517
Experimental thinning and pruning of Ponderosa pine

E.P. 534
Spacing trial of Douglas-fir, 16 Creek Vancouver Island
S.A.Y. Omule

E.P. 549
White spruce espacement trial, Anzac and Buckhorn Lake
L.J. Herring

E.P. 570
Espacement trial of Sitka spruce, Terrace
J. Pollack

E.P. 571
Tree species and espacement trial, west coast Vancouver Island
S.A.Y. Omule

E.P. 586
.01 Comparison of four age-classes of Douglas-fir planting stock 21 years after planting
G. Krumlik

E.P. 589
Survival and initial growth of morphologically defined classes of Douglas-fir planting stock on high site lands subject to dense cover
F.T. Pendl

E.P. 599
Coastal Douglas-fir provenance study
C.C. Ying

E.P. 607
Effects of initial spacing of the growth and development of Ponderosa pine
C.F. Thompson

E.P. 611
Trial of species and provenances: Jennis Bay
C.C. Ying

E.P. 618
Cone crop periodicity in spruce, Nelson Forest Region
C.F. Thompson

E.P. 626
Engelmann spruce planting trials 1964
C.F. Thompson

E.P. 630
Effects of juvenile spacing on individual tree growth in overstocked stands of lodgepole pine, Sheraton
J. Pollack

E.P. 640
Requirements of conifer seedlings for mineral nutrients
R. van den Driessche

E.P. 643
Prediction of nutrient status in Douglas-fir by foliar analysis
R. van den Driessche

E.P. 646
Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Prince George plantations
G.K. Kiss

E.P. 648
Grafting in Douglas-fir
I. Karlsson

E.P. 652
Dormancy and frost hardiness
R. van den Driessche

E.P. 657
Variation in lodgepole pine with particular reference to British Columbia
C.C. Ying

E.P. 660
Trial of tree species and espacement in the Sub-Boreal Spruce Biogeoclimatic Zone
L.J. Herring

E.P. 662
An altitudinal test of a low elevation seed source of Engelmann spruce, Larch Hills and McGillivray Lake
G. Kiss

E.P. 667
Vegetative reproduction in spruce
R.van den Driessche

E.P. 670
Genetic improvement of interior spruces
G.K. Kiss

E.P. 671
Spacing trials in lodgepole pine
M.B. Clark, J. Pollack, L.J. Herring

E.P. 672
Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Prince Rupert plantations
G.K. Kiss

E.P. 688
Douglas-fir provenance plantations, Prince George Forest Region
L.J. Herring

E.P. 692
Shore pine spacing and provenance trial
C.C. Ying

E.P. 693
Testing selective herbicides for bareroot and container nurseries
R. van den Driessche

E.P. 695
Effect of planting season and stock type on lodgepole pine seedling performance
J. Pollack, G. Krumlik

E.P. 699
Propagation and evaluation of lodgepole pine breeding material
C.C. Ying

E.P. 702
Geographic variation in Sitka spruce
C.C. Ying

E.P. 703
Responses of immature Douglas-fir and western hemlock to thinning and fertilizer application
P.R. Barker, G.A. Godfrey

E.P. 705
Spruce Piceta, Chilliwack and Red Rock
G.K. Kiss

E.P. 707
A progeny test of coastal Douglas-fir using a factorial mating design with four male testers
J.C. Heaman

E.P. 708
Breeding program of coastal Douglas-fir
J.C. Heaman

E.P. 710
Interior Douglas-fir breeding arboretum
B. Jaquish

E.P. 711
Western larch breeding arboretum
B. Jaquish

E.P. 712
Tree species trial in the Kitimat Valley
J. Pollack

E.P. 737
Cold storage physiology of conifer seedlings
W.D. Binder

E.P. 746
Physiological aspects of nursery production and field establishment of lodgepole pine, white spruce and interior Douglas-fir
A.N. Burdett

E.P. 747
Overwintering of conifer nursery stock
R. van den Driessche

E.P. 750
Yellow-cedar plantation at Cowichan Lake Research Station
I. Karlsson

E.P. 753
Nursery experiments with mineral nutrients
R. van den Driessche

E.P. 759
High elevation species and stock type trials
J.T. Arnott (CFS), F.T. Pendl

E.P. 764
Induction of dormancy and frost hardiness in western hemlock planting stock
W.D. Binder (ex. Cheung)

E.P. 770
Genetic improvement of lodgepole pine
M. Carlson

E.P. 771
Photoperiod extension for growth acceleration and flower promotion in lodgepole pine
M. Carlson

E.P. 773
Storage conditions and viability testing for coniferous pollen
J.E. Webber

E.P. 776
Correlations between quantitative and qualitative attributes
F.C.H. Yeh

E.P. 777
Rehabilitation of landings and skid trails in the Cariboo Forest Region
A. Vyse

E.P. 778
Experimental population genetics in conifers (Electrophoresis)
F.C.H. Yeh

E.P. 779
Root development after planting
I. Karlsson

E.P. 780
Flower stimulation in Douglas-fir
I. Karlsson

E.P. 781
Development of reforestation methods for avalanche control
C.F. Thompson

E.P. 782
Soil stability on the Queen Charlotte Islands
D.J. Wilford

E.P. 786
Nursery seedbed density and seedling spacing
R. van den Driessche

E.P. 789
Growth enhancement options for dense immature lodgepole pine stands
L.J. Herring

E.P. 790
Plantation trials in the Kamloops Forest Region

E.P. 791
Chemical control of root morphogenesis in container seedlings
A.N. Burdett

E.P. 793
Ecosystems of the coast-interior ecotone in southwestern British Columbia
K. Klinka

E.P. 799
Enhancement of cone production in seed orchards
J.E. Webber

E.P. 800
Evaluation of drag scarification treatments in the Prince George Forest Region
L.J. Herring

E.P. 804
Identification of factors influencing the natural regeneration of lodgepole pine
J. Pollack

E.P. 814
Tree species trial on the Queen Charlotte Islands
J. Pollack

E.P. 815
Amabilis fir arboretum
I. Karlsson

E.P. 818
Hydroseeding logging roads for stabilization and resource protection
S.G.J. Homoky

E.P. 819
Open-pollinated progeny testing for interior spruce seed orchard establishment
G.K. Kiss

E.P. 821
Supplemental pollination in seed orchards
J.E. Webber

E.P. 822
Ecosystem classification program for the Ministry of Forests
J.D. Lousier, D.V. Meidinger

E.P. 823
Grand fir provenance study
C.C. Ying

E.P. 824
Amabilis fir provenance study
C.C. Ying

E.P. 827
Root dipping and foliage treatments to improve seedling survival and growth
D.G. Simpson

E.P. 835
The effect of soaking seeds on germination of some major B.C. forest trees
C. Leadem

E.P. 836
Nursery cultural treatments for enhanced stock quality at interior nurseries
D.G. Simpson

D.P. 838
Quick tests to determine seed quality
C. Leadem

E.P. 841
Development of silvicultural prescriptions for drybelt Douglas-fir sites in the Cariboo Forest Region
A. Vyse

E.P. 842
The effects of stand density on the top height of lodgepole pine stands in the Cariboo forest Region
A. Vyse

E.P. 843
Seed sizing and sorting
C. Leadem

E.P. 845
The effects of hare and squirrel damage on managed stands in the B.C. interior
T.P. Sullivan

E.P. 846
The effects of undercutting and wrenching in the nursery on seedling quality
R. van den Driessche

E.P. 848
Improving seed performance
C. Leadem

E.P. 850.01
Development and application of the lodgepole growth model (TASS-P1)
J.W. Goudie, K.J. Mitchell

E.P. 850.02
Investigation of the causes of stagnation in lodgepole pine stands
K.J. Mitchell

E.P. 851
Accelerated growth of seedlings to induce early and abundant cone production
J.E. Webber

E.P. 852
Test of lethal trap techniques for spruce beetle control
J. Pollack, P. Hall

E.P. 854
An evaluation of the information function of Research Branch
T.D. Mock

E.P. 855
Investigations of the forest water balance and tree growth
T.A. Black

E.P. 857
Noble fir provenance study
C.C. Ying

E.P. 858
New methods for the production of forest planting stock
A.N. Burdett

E.P. 859
Early growth and survival of interior spruce stock types
R. van den Driessche
A. Vyse

E.P. 861
Range fertilization
B. Wikeem

E.P. 862
Fish/forestry interactions program
V.A. Poulin

E.P. 863
The propagation and establishment of tree and shrub species for erosion control
S.G.J. Homoky

E.P. 865
Container seed orchard research
S.D. Ross

E.P. 866
Conditioning/fertilizer trials in 2+0 nursery stock
D.G. Simpson

E.P. 867
Tree Injector System
B. Dillistone, W. Bergerud

E.P. 868
Ecological investigations of wildfires in northern B.C.
D.V. Meidinger, J.J. Pojar, R.L. Trowbridge

E.P. 869
Seedling quality research
D.G. Simpson

E.P. 870
Fate of nitrogenous fertilizers applied to snow
V. Marshall (CFS)

E.P. 871
Intensive foresty practices and wood quality
K. Illingworth

E.P. 873
Effect of cone storage on seed viability
C. Leadem

E.P. 874
Monitoring cone and seed performance
C. Leadem

E.P. 877
Production of nursery stock in composted sewage sludge
D.G. Simpson

E.P. 885
Development of vegetation management techniques for Coastal alluvial sites

E.P. 886
Fertilizing and thinning in interior forests
P.R. Barker, R.P. Brockley, D.A. Draper

E.P. 887
A biological study of the dry south-central region of B.C.
T.T. McIntosh

E.P. 888
Ecological description and classification of grasslands
T. Lester

E.P. 893
Ecophysiological studies of regeneration problems in the interior of B.C.
J. Bassman

E.P. 894
Potentially damaging insects in intensively managed stands of interior lodgepole pine
A. Vyse

E.P. 895
Potentially damaging diseases in intensively managed stands of interior lodgepole pine
A. Vyse

E.P. 902
Soil moisture regimes on forested slopes
R. Laird

E.P. 903
Habitat relationships of mule-deer in the Interior Douglas Fir Zone of central British Columbia
H.M. Armleder

E.P. 904
Tree species in the Cariboo Forest Region
A. Vyse

E.P. 907
Investigation of site effects on lodgepole pine flowering
M. Carlson

E.P. 909
Pelleting tree seed to improve sowing precision and efficiency
C. Leadem

E.P. 910
The effects and control of lodgepole pine dwarf mistletoe in the Cariboo Forest Region
A. Vyse

E.P. 912
Roosevelt elk/intensive forestry interactions
D.W. Janz

E.P. 914
Developing a wildlife-habitat management system (MANATAT)
K. Scoullar

E.P. 915
An adaptive systems approach for the research program on integrated wildlife-intensive forestry on Vancouver Island
D. Eastman

E.P. 916
Effects of intensive forest management on non-ungulate wildlife
K. Sadoway

E.P. 918
Mineral nutrition of seed orchard trees
R. van den Driessche

E.P. 920
Investigations of soil temperature in ecosystems of the Prince Rupert Forest Region
R.L. Trowbridge, K. McKeown

E.P. 922
The effect of spacing on the growth and yield of lodgepole pine
W.D. Johnstone

E.P. 923
Black-tailed deer in second growth forests on Vancouver Island
S. McNay

E.P. 925
Improved methods of sampling design
D. Errico, V. Fletcher, W. Bergerud

E.P. 926
Improved methods of experimental design
D. Errico, W. Bergerud, V. Fletcher

E.P. 927
Development and application of the Douglas fir growth model (TASS-Df)
K.J. Mitchell

E.P. 928
Quality control in the production of nursery planting stock
A.N. Burdett

E.P. 930
An ecosystematic approach to silvicultural management of immature forests — Sayward Forest Study
K. Klinka, R.N. Green, J.B. Nyberg

E.P. 931
A problem analysis of grassland classification
A. Nicholson

E.P. 932
An investigation of topophysis in the repression of lodgepole pine
D.A. Draper

E.P. 933
Planting site and stock treatments for brushfield conversion
L. Herring

E.P. 934
Intensive forestry effects on Vancouver Island deer and elk habitats
J.B. Nyberg

E.P. 935
Hormone treatment methods and regimes for seed trees
S.D. Ross

E.P. 936
Problem Analysis: Interactions Among Forestry, Range and Wildlife Management in the East Kootenays
M.D. Pitt

E.P. 939
Caribou-forestry interactions in B.C.
D.F. Hatler, S.K. Stevenson

E.P. 940
Cone and seed technology development
C. Leadem

E.P. 941
Reproductive cycle of B.C. conifer genera, booklet series
J.N. Owens

E.P. 942
Ecosystem mapping

E.P. 944
Seed orchard crown management
S.D. Ross

E.P. 946
Improving early growth after outplanting
R. van den Driessche

E.P. 947
Investigations of atmospheric and soil climate in the Dome Creek – McBride – Valemount Area of the Rocky Mountain Trench
W. Blashill, G.D. Hope, A.J. McLeod

E.P. 948
Improving cultural techniques for the propagation of northwest conifers

E.P. 949
Techniques for determining shrub biomass from auxiliary plant variables and evaluation of methods for application in range inventory
J.W. Schwab

E.P. 950
An evaluation of sampling and analysis systems for wildlife habitat analysis
R. Page

E.P. 951
Wildlife habitat handbooks for the forests and rangelands of B.C. and associated projects
A. Harcombe

E.P. 952
Coastal grizzly bear – forest harvesting interactions
R. Archibald (F&W)

E.P. 953
Prescribed fire ecology studies in the Prince Rupert Forest Region
A.M. Macadam

E.P. 954
Range research needs for British Columbia
B. Wikeem

E.P. 955
Evaluation of quantitative sampling methods for determining the importance of cryptogams as indicators of range site potential and condition of B.C. grasslands
T. McIntosh

E.P. 956
Upper Penticton Creek experimental watershed study
J.D. Cheng

E.P. 957
Foliar analysis studies in the Prince Rupert Forest Region
R. Trowbridge, D. Yole

E.P. 958
Needle cast following greenhouse growing of western hemlock
W.D. Binder

E.P. 959
Rain-on-Snow Hydrology in the Queen Charlotte Islands, British Columbia
D. J. Wilford

E.P. 960
Mitotic index as an indicator of dormancy, lifting and frost hardiness status of conifers
W.D. Binder

E.P. 961
Horticulture of containerized seed orchard trees
A.M. Eastham

E.P. 962
A comprehensive study to determine the effects of initial espacement and subsequent thinning on the growth and yield of lodgepole pine plantations
W.D. Johnstone

E.P. 963
Quantification of soil nutrient regimes in the Prince George Forest Region
G.D. Hope, A.J. McLeod

E.P. 964
Espacement trials in the Prince Rupert Forest Region
D. Coates

E.P. 965
Operations research applications to seed orchard and nursery stock production systems
D. Errico, I. Karlsson, D. Carson

E.P. 966
Post-planting spruce ecophysiology
D. Draper, D. Lousier, D. Spittlehouse, W. Binder, R. McMinn

E.P. 967
Snow accumulation and melt on forested and clearcut sites in the West Kootenays, British Columbia
D. Toews

E.P. 968
Ecosystem Mapping in the Prince Rupert Forest Region
S. Lindeburgh, R. Trowbridge

E.P. 969
Studies of nitrogen fixation in forest ecosystems in the Prince George Forest Region
C. DeLong, A. McKinnon, G. Hope

E.P. 970
Forest vegetation management in B.C.

E.P. 971
Biological stress concepts in white spruce reforestation

E.P. 972
The biological effectiveness of site preparation techniques in the Bowron River valley

E.P. 973
A demonstration of managed stand species productivity

E.P. 974
The effect of season and treatment on the release response of suppressed Douglas-fir saplings
R.E. Bigley

E.P. 975
Development and application of the white spruce growth model (TASS-Sw)
J.W. Goudie, K.J. Mitchell

E.P. 976
Genetic improvement of interior Douglas-fir
B. Jaquish

E.P. 977
Biochemistry of cone production responses to nitrogen fertilizer
L. Ebell

1983-84 RESEARCH PUBLICATIONS

Annas, R.M. 1983. Boreal White and Black Spruce Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 254-258.

Banner, A., J. Pojar and G.E. Rouse. 1983. Postglacial paleocology and successional relationships of a bog woodland near Prince Rupert, British Columbia. Can. J. For. Res. 13:938-947.

Burdett, A.N. and D.G. Simpson. 1984. Lifting, grading, packaging and storing bareroot nursery stock. Chapter 21. In Forest nursery manual: production of bareroot nursery seedlings. M. Duryea and T. Landis (editors). Martinus Nijhoff, The Hague.

Cameron, I.R. 1983. Who can model site curves? In Proc. 2nd Pacific Coast Conf. on Mathematical Modelling of Renewable Resources. Vol. II R.H. Lamberson (editor). Humboldt State University, Mathematical Modelling Group, Arcata, Cal., (Mtg. held in Victoria, B.C., May 5-7, 1983). pp. 129-133.

Carter, R.E., J. Otchere-Boateng and K. Klinka. 1984. Dieback of a 30-year old Douglas-fir plantation in the Brittain River Valley, British Columbia: symptoms and diagnosis. For. Ecol. Manage. 7:249-263.

Coupé, R. 1983. Engelmann Spruce – Subalpine Fir Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 273-277.

Courtin, P.J., M.C. Feller and K. Klinka. 1983. Lateral variability in some properties of disturbed forest soils in southwestern British Columbia. Can. J. Soil Sci. 63:529-539.

Godfrey, G.A. and D.K. Garthwaite. 1984. Rapid assessment of outerwood specific gravity in live trees using a pocket durometer. Can. J. For. Res. 14:145-150.

Johnstone, W.D. 1984. Influence of stand age on planted white spruce and lodgepole pine. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-256. 19 p.

Ketcheson, M.V., T.F. Braumandl and G. Utzig. 1983. Interior Cedar – Hemlock Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 277-282.

Klinka, K. 1983. Coastal Douglas-fir Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 263-267.

Leadem, C.L. and D.G.W. Edwards, 1984. A multiple-compartment tree seed tumbler-drier. Tree Planters Notes 35:23-25.

Meidinger, D. and J. Pojar. 1983. Sub-Boreal Spruce Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 306-311

Mitchell, W.R. 1983. Montane Spruce Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 288-291

Mitchell, W.R. and W.R. Erickson. 1983. Interior Douglas-fir Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 282-287.

Mitchell, W.R. and W.R. Erickson. 1983. Ponderosa Pine – Bunchgrass Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 296-301.

Omule, S.A.Y. 1983. Use of a known coefficient of variation in estimating change. In Proc. Int. Conf. Renewable Resource Inventories for Monitoring Changes and Trends. J.F. Bell and T. Atterbury (editors). College of Foresty, Oregon State University, Corvallis, Oregon. pp. 600-603.

Omule, S.A.Y. 1983. Sample size for estimating tree height-diameter relationships. In Proc. 2nd Pacific Coast Conf. on Mathematical Modelling of Renewable Resources. Vol. II R.H. Lamberson (editor). Humboldt State University, Mathematical Modelling Group, Arcata, Cal., (Mtg. held in Victoria, B.C., May 5-7, 1983). pp. 144-145.

Owens, J.N. and M. Molder. 1984. The reproductive cycle of lodgepole pine. B.C. Min. For., Research Branch, Victoria, B.C.

Owens, J.N. and M. Molder. 1984. The reproductive cycle of interior spruce. B.C. Min. For., Research Branch, Victoria, B.C.

Owens, J.N. and M. Molder. 1984. The reproductive cycle of western and mountain hemlock. B.C. Min. For., Research Branch, Victoria, B.C.

Owens, J.N. and M. Molder. 1984. The reproductive cycle of wester redcedar and yellow-cedar. B.C. Min. For., Research Branch, Victoria, B.C.

Page, R.E. 1984. Managing moose with the knowledge of population dynamics theory. Alces 19:83-97

Peterson, R.O. and R.E. Page. 1983. Cyclic fluctuation of wolves and moose on Isle Royale, Michigan, USA. Acta Zool. Fennica 174:252-254.

Pojar, J. (compiler and editor). 1983. Forest ecology. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 221-318

Pojar, J. 1983. Alpine Tundra Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 248-253

Pojar, J. 1983. Coastal Cedars – Pine – Hemlock Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 258-263.

Pojar, J. 1983. Spruce – Willow – Birch Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 301-306.

Pojar, J. and K. Klinka. 1983. Coastal Western Hemlock Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 267-272.

Pojar, J. and K. Klinka. 1983. Mountain Hemlock Zone. In Forestry handbook for British Columbia. 4th ed. S.B. Watts (editor). Forestry Undergraduate Society, U.B.C., Vancouver, B.C., pp. 291-296.

Pojar, J., R. Trowbridge and D. Coates. 1984. A guide to the Sub-Boreal Spruce Zone in the Prince Rupert Forest Region. B.C. Min. For. Land Management Report No. 17. 298 p. + Supplement.

Ross, S.D. 1983. Enhancement of shoot elongation in Douglas-fir by gibberellin $A_{4/7}$ and its relation to the hormonal promotion of flowering. Can. J. For. Res. 13:986-994.

Ross, S.D., R.P. Pharis and W.D. Binder. 1983. Growth regulators and conifers: their physiology and potential uses in forestry. In Plant growth regulating chemicals. Vol. 2. L.G. Nickell (editor). CRC Press, Boca Raton, Fla., pp. 35-78

Sullivan, T.P. and D.S. Sullivan. 1983. Use of index lines and damage assessments to estimate population densities of snowshoe hares. Can. J. Zool. 61:163-167.

Sullivan, T.P. and D.S. Sullivan. 1984. Influence of range seeding on rodent populations in the Interior of British Columbia. J. Range Mgmt. 37(2):163-165.

Trowbridge R. 1984. Prediction of some soil thermal regimes in northwestern British Columbia with comparisons to the soil climate map of Canada and soil temperature classes used for Canada. In 5th Annual Proc. Expert Committee on Soil Survey. Land Resource Research Institute, Ottawa, Ont.

van den Driessche, R. 1983. Rooting of Sitka spruce cuttings from hedges, and after chilling. Developments in Plant and Soil Science 7:495-499.

van den Driessche, R. 1984. Soil fertility in forest nurseries. Chapter 7. In Forest nursery manual: production of bareroot nursery seedlings. M. Duryea and T. Landis (editors). Martinus Nijhoff, The Hague.

Wood J.H., G.M. Blake and F.W. Allendorf. 1983. Amount and distribution of isozyme variation in Ponderosa Pine from eastern Montana. Silvae Genetica 32:5-6, 151-157.

Ying, C.C. 1983. Provenance research by the British Columbia Ministry of Forests. In Proc. 19th Meeting of the Canadian Tree Improv. Assoc. Duncan, B.C., pp. 207-209.

EMPLOYEES OF THE MINISTRY OF FORESTS, RESEARCH BRANCH

EMPLOYEE	POSITION	LOCATION
Dangerfield, Dr. J.A. (Jim)	Director	Victoria
Mock, T.D. (Tim)	Communications Co-ordinator	Victoria
Montgomery, G. (Georgina)	Communications Assistant	Victoria
	SYSTEMS AND BIOMETRICS	
Kovats, M. (Mik)	Manager	Victoria
Bergerud, W. (Wendy)	Biometrician	Victoria
Buchmueller, E. (Elsie)	Data Control Clerk	Victoria
Cameron, I. (Ian)	Biometrician	Victoria
Errico, D. (Darrell)	Technical Advisor, Biometrics-Exp. Design	Victoria
Fletcher, V. (Val)	Biometrician	Victoria
Geils, D. (Dale)	Biometric Clerk	Victoria
Mitchell, Dr. K.J. (Ken)	Technical Advisor, Biometrics-Simulation	Victoria
Roberge, R. (Roger)	Systems Analyst	Victoria
	SILVICULTURE	
Benskin, H.J. (Henry)	Manager	Victoria
Barker, Dr. P.R. (Paul)	Silviculturist, Forest Productivity	Victoria
Brockley, R. (Rob)	Ass't Silviculturist, Forest Productivity	Vernon
Clark, B. (Bruce)	Forest Research Officer	Kamloops
Coates, H. (Harry)	Research Technician	Prince George
D'Anjou, B. (Brian)	Assistant Forest Research Officer	Vancouver
Draper, Dr. D. (Dale)	Silviculturist, North	Red Rock
Elmes, E. (Ed)	Research Technician	Kamloops
Fahlman, R. (Rick)	Ass't Silviculturist North	Red Rock
Gulsharn, M. (Megji)	Office Assistant	Vancouver
Herring, L. (Les)	Forest Research Officer	Prince George
Homoky, S.G.J. (Stephen)	Silviculturist, Rehabilitation	Victoria
Johnstone, Dr. W.D. (Wayne)	Silviculturist, South	Vernon
Krumlik, Dr. G.A., (George)	Silviculturist, Reforestation	Victoria
Letchford, T. (Tony)	Biologist	Red Rock
Mitchell, W. (Warren)	Research Technician	Cariboo
Omule, Dr. S.A.Y. (Stephen)	Silviculturist, Growth & Yield Analysis	Victoria
Pendl, F. (Frank)	Forest Research Officer	Vancouver
Pollack, J. (John)	Forest Research Officer	Prince Rupert
Romeo, M. (Maria)	Research Clerk	Prince Rupert
Sheran, F. (Frank)	Research Technician	Cariboo
Shishkov, G. (George)	Research Technician	Vancouver
Thompson, C. (Chris)	Forest Research Officer	Nelson
Van Thienen, F. (Frank)	Technician	Prince Rupert
Vyse, A. (Alan)	Forest Research Officer	Cariboo
Wray, P. (Pat)	Research Technician	Nelson
	TREE IMPROVEMENT	
Illingworth, K. (Keith)	Manager	Victoria
Anderson, S.A. (Svend)	Superintendent	Red Rock
Ashbee, D.P. (Doug)	Provenance Technician	Victoria
Atwood, L. (Lynne)	Research Technician	Vernon
Benneke, G. (Gisela)	Research Technician	Vernon
Bowen, B. (Brian)	Machine Operator	Cowichan Lake
Cairns, I. (Ian)	Nursery Technician	Cowichan Lake
Carlson, Dr. M. (Mike)	Tree Breeder, Lodgepole pine	Vernon
Carson, D. (Don)	Superintendent Nursery & Camp	Cowichan Lake

EMPLOYEE	POSITION	LOCATION
Connolly, D. (Dan)	Machine Operator	Cowichan Lake
Cook, A. (Anne)	Receptionist Clerk	Cowichan Lake
Ferguson, N. (Nellarene)	Receptionist Clerk	Vernon
Hattie, R.N. (Bob)	Tree Breeding Technician	Victoria
Hayton, L. (Lisa)	Tree Breeding Assistant	Victoria
Heaman, J.C. (Chris)	Tree Breeder, Coastal Douglas-fir	Victoria
Jaquish, B. (Barry)	Tree Breeder, Interior Douglas-fir	Vernon
Jensen, H. (Henning)	Gene Archive Technician	Cowichan Lake
Karlsson, S.A.I. (Ingemar)	Manager, Cowichan Lake Research Station	Cowichan Lake
Kiss, G.K. (Gyula)	Tree Breeder, Interior Spruce	Vernon
McLaughlin, S.D. (Shelley)	Research Technician	Vernon
Meagher, Dr. M. (Mike)	Tree Breeder, Western Hemlock	Victoria
Murphy, J. (John)	Tree Breeding Technician	Red Rock
Ogg, J. (John)	Propagation Technician	Cowichan Lake
Patton, D. (Don)	Building Maintenance Man	Cowichan Lake
Phillips, G. (Gisele)	Research Technician	Vernon
Pilcher, L. (Les)	Flunkey	Cowichan Lake
Pomeroy, N. (Norman)	Research Technician	Victoria
Pryhitka, B. (Bev)	Lab Technician	Victoria
St. Pierre, D.J. (Don)	Provenance Technician	Victoria
Swank, E. (Evelyn)	Junior Propagation Technician	Cowichan Lake
Taylor, W. (Bill)	Propagation Technician	Red Rock
Trust, D. (Diane)	Lab Scientist	Victoria
Wallden, D.R. (Dave)	Tree Breeding Technician	Vernon
Wesenberg, D. (Dale)	Building Maintenance	Vernon
White, R.L. (Ralph)	Provenance Technician	Victoria
Wilkinson, A. (Alan)	Cook	Cowichan Lake
Wood, A. (Anne)	Research Officer	Cowichan Lake
Woods, J. (Jack)	Gene Archive Officer	Cowichan Lake
Woon, C. (Chio)	Tree Breeding Technician	Victoria
Wrenshall, B. (Barb)	Tree Breeding Assistant	Victoria
Yeh, Dr. F.C.H. (Francis)	Technical Advisor, Genetics	Victoria
Ying, Dr. C.C. (Cheng)	Provenance Forester	Victoria

TREE PHYSIOLOGY

Ebell, Dr. L.F. (Lorne)	Manager	Victoria
Baker, S. (Sue)	Research Technician	Research Lab, Victoria
Balderston, M.B. (Mike)	Superintendent, Research Laboratory	Research Lab, Victoria
Binder, Dr. W. (Wolfgang)	Physiologist, Nurseries	Research Lab, Victoria
Burdett, Dr. A.N. (Nigel)	Physiologist, Nurseries	Research Lab, Victoria
Calver, L. (Linda)	Receptionist Clerk	Research Lab, Victoria
Clark, J. (Joanne)	Lab Technician	Research Lab, Victoria
Corck, E. (Ted)	Senior Lab Technician	Research Lab, Victoria
Eastham, A. (Andrea)	Conifer Horticulturist	Research Lab, Victoria
Gomez, J. (José)	Research Technician	Research Lab, Victoria
Hedlin, D. (Doug)	Lab Technician	Research Lab, Victoria
Hollefreund, C. (Clint)	Research Technician	Research Lab, Victoria
Leadem, Dr. C. (Carole)	Tree Seed Physiologist	Research Lab, Victoria
Liu, A. (Andy)	Lab Technician	Research Lab, Victoria
Lort, J. (Jennifer)	Lab Technician	Research Lab, Victoria
Martin, P. (Peter)	Research Technician	Research Lab, Victoria
Mehl, H. (Helga)	Research Technician	Research Lab, Victoria
Nassif, L. (Lois)	Research Technician	Vernon
Painter, R. (Roger)	Research Technician	Research Lab, Victoria
Planden, R. (Ron)	Research Technician	Research Lab, Victoria
Ponsford, D. (Dave)	Research Technician	Research Lab, Victoria
Ralph, L. (Len)	Lab Technician	Research Lab, Victoria
Robertson, D. (Dave)	Research Technician	Research Lab, Victoria
Ross, Dr. S.D. (Steve)	Physiologist, Tree Improvement	Research Lab, Victoria
Shipton, G. (Glen)	Lab Assistant	Research Lab, Victoria
Simpson, D.G. (Dave)	Tree Physiologist,Interior	Vernon

EMPLOYEE	POSITION	LOCATION
Vallance, A.M.E. (Marilyn)	Supervisor, Analytical Lab	Research Lab, Victoria
van den Driessche, Dr. R. (Bob)	Senior Tree Physiologist	Research Lab, Victoria
Webber, Dr. J.E. (Joe)	Physiologist, Tree Improvement	Research Lab, Victoria
White, C.P. (Carl)	Research Technician	Research Lab, Victoria
	ECOLOGY AND EARTH SCIENCES	
Baker, Dr. T.E. (Ted)	Manager	Victoria
Angove, K. (Karen)	Research Biologist	Kamloops
Armleder, H. (Harold)	Wildlife Habitat Ecologist	Cariboo
Bancroft, B. (Bryce)	Resource Officer	Kamloops
Banner, A. (Allan)	Assistant Pedologist	Prince Rupert
Braumandl, T. (Tom)	Interpretation Forester	Nelson
Cheng, Dr. J. (Jack)	Hydrologist	Kamloops
Coates, D. (Dave)	Assistant Forest Research Officer	Prince Rupert
Coupé, R. (Ray)	Ecologist	Cariboo
Courtin, P. (Paul)	Assistant Pedologist	Vancouver
Dawson, R. (Rick)	Assistant Ecologist	Cariboo
Delong, C. (Craig)	Assistant Ecologist	Prince George
Doyle, K. (Kathy)	Research Clerk	Kamloops
Ellis, R. (Rick)	Manager, Wildlife Habitat	Victoria
Erickson, W. (Wayne)	Resource Officer	Kamloops
Faye, R. (Bob)	Assistant Pedologist	Prince George
Gluns, D. (David)	Assistant Hydrologist	Nelson
Green, R. (Bob)	Assistant Pedologist	Vancouver
Hamilton, E. (Evelyn)	Research Ecologist	Victoria
Hatter, I. (Ian)	Biologist	Victoria
Holmes, D. (Doug)	Instructor	Prince Rupert
Hope, Dr. G. (Graham)	Assistant Pedologist	Prince George
Jang, L. (Lori)	Assistant Technician	Prince George
Jenveys, S. (Steve)	Assistant Pedologist	Prince George
Kassay, K. (Kathy)	Ecologist Assistant	Vancouver
Ketcheson, M. (Maureen)	Ecologist	Nelson
Klinka, Dr. K. (Karel)	Research Pedologist	Vancouver
Laird, R. (Robert)	Assistant Pedologist	Vancouver
Lindeberg, S. (Scott)	Assistant Pedologist	Prince Rupert
Lloyd, D. (Dennis)	Research Forester	Kamloops
Lousier, Dr. D. (Dan)	Ecology Program Manager	Victoria
Macadam, A. (Anne)	Assistant Pedologist	Prince Rupert
McKeown, K. (Karen)	Technician	Prince Rupert
McKinnon, A. (Andy)	Ecologist	Prince George
McLeod, A. (Angus)	Pedologist	Prince George
McNay, S. (Scott)	Wildlife Habitat Ecologist	Victoria
Meidinger, D. (Del)	Classification Program Correlator	Victoria
Meister, R. (Ron)	Assistant Pedologist	Cariboo
Mitchell, R. (Bob)	Pedologist	Kamloops
Moss, I. (Ian)	Assistant Interpretations Forester	Prince Rupert
Newman, R. (Reg)	Ass't Range Scientist	Ag Can
Nicholson, A. (Alison)	Ecologist	Victoria
Nuszdorfer, F. (Fred)	Research Forest Ecologist	Vancouver
Nyberg, B. (Brian)	Research Wildlife Ecologist	Vancouver
Nystedt, P. (Paul)	Botanical Illustrator	Victoria
Page, R. (Rick)	Wildlife Habitat Analysis	Victoria
Peterson, L. (Les)	Ass't Wildlife Habitat Ecologist	Campbell River
Pojar, Dr. J. (Jim)	Ecologist	Prince Rupert
Ray, C. (Cheryl)	Wildlife Habitat Ecologist	Campbell River
Roberts, A. (Anne)	Assistant Ecologist	Cariboo
Roddan, B. (Bruce)	Lab Technician	Kamloops
Russell, F. (Fraser)	Resource Officer	Kamloops
Sadoway, K. (Karen)	Ass't Wildlife Habitat Ecologist	Victoria
Saver, L. (Lynn)	Clerk	Kamloops
Scagel, A. (Anne)	Assistant Forest Ecologist	Vancouver

EMPLOYEE	POSITION	LOCATION
Schwab, J. (Jim)	Research Extension Forester	Prince Rupert
Spittlehouse, Dr. D. (Dave)	Climatologist	Victoria
Steen, O. (Ordell)	Research Ecologist	Cariboo
Stewart, W. (Bill)	Research Technician	Kamloops
Still, G. (Gerry)	Pedologist	Nelson
Stordeur, L. (Linda)	Ass't Wildlife Habitat Analyst	Victoria
Thompson, C. (Carol)	Illustrator	Cariboo
Thompson, S. (Steve)	Assistant Pedologist	Nelson
Thomson, R. (Rob)	Ass't Wildlife Habitat Ecologist	Cariboo
Toews, D. (Dave)	Hydrologist	Nelson
Trowbridge, R. (Rick)	Research Pedologist	Prince Rupert
Vold, C. (Cecily)	Ecology Clerk	Victoria
Warner, A. (Alison)	Ecologist	Nelson
Watt, W. (Bill)	Pedologist	Cariboo
Wikeem, B. (Brian)	Range Scientist	Kamloops
Wilford, D. (Dave)	Hydrologist	Prince Rupert
Williams, D. (Duncan)	Assistant Pedologist	Prince George
Yee, A. (Art)	Assistant Pedologist	Cariboo
Yole, D. (Dave)	Assistant Pedologist	Prince Rupert
	SUPPORT SERVICES	
Archibald, G. (Gail)	Manager	Victoria
Appleyard, L. (Linda)	Records Clerk	Victoria
Chester, P.W. (Pat)	Senior Clerk	Victoria
Edgell, K. (Karen)	Receptionist	Victoria
Fraser, L. (Linda)	Word Processor Operator	Victoria
Gallant, D. (Denise)	Clerical Assistant	Victoria
Garthwaite, K. (Keith)	Draughtsman	Victoria
Lomas, E. (Edna)	Word Processor Operator	Victoria
Rees, V. (Vivian)	Word Processor Operator	Victoria
Ward, C. (Cheryl)	Word Processor Supervisor	Victoria

ADDRESSES

RESEARCH BRANCH
B.C. Ministry of Forests
1450 Government Street
Victoria, B.C. V8W 3E7

RESEARCH LABORATORY
4300 North Road
Victoria, B.C. V8Z 5J3

COWICHAN LAKE RESEARCH STATION
Box 335, Mesachie Lake, B.C., V0R 2N0

KALAMALKA RESEARCH STATION AND SEED ORCHARD
Ministry of Forests
3401 Reservoir Road
Vernon, B.C. V1B 2C7

RED ROCK NURSERY
R.R. #7, R.M.D. #6
Prince George, B.C., V2N 2J5

RANGE RESEARCH STAFF
c/o AGRICULTURE CANADA
Research Station
3015 Ord Road
Kamloops, B.C, V2B 8A9

CARIBOO FOREST REGION
Research Section
540 Borland Street
Williams Lake, B.C.
V2G 1R8

CAMPBELL RIVER FOREST DISTRICT
Research Section
370 South Dogwood Street
Campbell River, B.C.
V9W 6Y7

VANCOUVER FOREST REGION
Ministry of Forests
4595 Canada Way
Burnaby, B.C. V5G 4L9

NELSON FOREST RESEARCH
Ministry of Forests
518 Lake Street
Nelson. B.C. V1L 4C6

KAMLOOPS FOREST REGION
Ministry of Forests
515 Columbia Street
Kamloops, B.C. V2C 2T7

PRINCE GEORGE FOREST REGION
Ministry of Forests
1011 - 4th Avenue
Prince George, B.C. V2L 3H9

PRINCE RUPERT FOREST REGION
Ministry of Forests
Bag 5000
Smithers, B.C. V0J 2N0